THE

# CHEMISTRY OF THE ARTS;

BEING

## A PRACTICAL DISPLAY

OF THE

## ARTS AND MANUFACTURES

WHICH DEPEND

*ON CHEMICAL PRINCIPLES.*

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With Numerous Engravings.

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ON THE BASIS OF

## GRAY'S OPERATIVE CHEMIST,

ADAPTED TO THE UNITED STATES;

WITH

TREATISES ON CALICO PRINTING, BLEACHING, AND OTHER LARGE ADDITIONS.

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BY ARTHUR L. PORTER,

LATE PROFESSOR OF CHEMISTRY IN THE UNIVERSITY OF VERMONT.

Philadelphia:

CAREY & LEA.

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EASTERN DISTRICT OF PENNSYLVANIA, To wit:

BE IT REMEMBERED, that on the twenty-first day of October, in the fifty-fifth year of the Independence of the United States of America, A. D. 1830,

CAREY & LEA,

of the said district, have deposited in this office the title of a book the right whereof they claim as proprietors, in the words following, to wit:

"The Chemistry of the Arts; being a Practical Display of the Arts and Manufactures which depend on Chemical Principles. With numerous Engravings. On the Basis of Gray's Operative Chemist, adapted to the United States; with Treatises on Calico Printing, Bleaching, and other large Additions. By Arthur L. Porter, late Professor of Chemistry in the University of Vermont."

In conformity to the Act of the Congress of the United States, entitled, "An Act for the Encouragement of Learning, by securing the Copies of Maps, Charts, and Books, to the Authors and Proprietors of such Copies, during the times therein mentioned"—And also to the Act, entitled, "An Act supplementary to an Act, entitled, 'An Act for the Encouragement of Learning, by securing the Copies of Maps, Charts, and Books, to the Authors and Proprietors of such Copies, during the times therein mentioned,' and extending the benefits thereof to the arts of designing, engraving, and etching historical and other prints."

D. CALDWELL,

*Clerk of the Eastern District of Pennsylvania.*

# PREFACE.

The want of a book peculiarly devoted to the general practice of the Chemical Arts and Manufactures has been long felt. The practical chemists have been left to find out what they wanted amidst a heap of extraneous matter in Dictionaries, Encyclopædias, or in systems in which the theory of chemistry was the principal object; and all of these sources being written in the new language of the day in which they were published, necessitated the mere practical man to learn the language and theory of that day, to his great loss of time, so that he frequently threw away the book in disgust, rather than encounter this difficulty.

The English library is peculiarly deficient in works upon the chemical arts. In the reign of Charles II. a few books on these subjects made their appearance, as Stalker on Japanning, Purfoot on Dyeing, a small work, but which contains the most accurate information, and which Dr. Bancroft allows not to be surpassed by any subsequent work on the subject. The processes of a few chemical arts, as refining, and the making of copperas and alum, were given in the Philosophical Transactions, and Mr. Ray, at the end of his English Proverbs, has given an account of the processes used at the mineral works of his time. In the perusal of these books it is astonishing to find how few and slight are the differences between the old prac-

tice and that of the present day. Larger capitals are employed, and more elegant forms given to the articles produced, but the real substantial parts of the processes used still remain nearly as they were. For this improvement in the forms, we are indebted to the Society for the Encouragement of Arts, Manufactures, and Commerce.

At present, the publication of the letters patent taken out by various projectors, in the Repertory of Arts, and other periodical publications, furnish the principal sources of information respecting these arts. And the incidental information they give of the actual practice, is for the most part far more valuable than the new schemes that they propose for its amendment.

To collect this information, and to join with it what could be found in the two great French Encyclopædias, the Dictionnaire Technologique, now in course of publication, and in several foreign periodical works, in which the chemical arts form a part of the plan, has been the object of the author. How far he has succeeded, must be left to the reader to judge. It is, however, necessary to state, that the author has laboured nearly the whole time, and especially towards the end, under the pressure of the severest illness, so that his life was, and is still, despaired of, and therefore he solicits a favourable view of any mistakes into which he may have fallen, or any omissions of which he may be guilty.

It has not been thought advisable to adopt all the alterations in nomenclature to which the progress of chemical science is continually giving rise, but rather

to avoid, as much as possible, substituting names newly given to substances, for those by which they have hitherto been distinguished. It is particularly requested that it may be distinctly understood that no opinion whatever is offered by the author upon the soundness of the numerous alterations which are daily taking place in the different schools, but that the popular nomenclature has been adhered to simply because it is popular, and the Lavoisierian nomenclature in other cases, because it is very doubtful whether the advantage of what may possibly be a more perfect nomenclature, is not surpassed by the disadvantage of perplexing the memory of indifferent and uninformed persons with changes, the propriety of which is only felt by the accomplished philosophical Chemist.

There is another reason that real practical Chemists should avoid habituating themselves to continual changes of names, lest they should have occasion to take out letters patent for any invention of their own. For it being an essential point that the invention should be so plainly described that any person may, at the expiration of the term, produce the like, the Court of King's Bench determined, in the case of Savory against Price and Son, that the composition of the Seidlitz powders not being described under the popular names, and in the plainest manner, the letters patent were themselves void. It being necessary that patentees should use the popular language, and denominate the several substances by the names under which they are known in the Book of Rates, and the Statutes of the Realm; and if not to be found there, by the most usual names under which they are sold by the dealers in them, to workmen and others, and that if articles are

used which are on sale, they must be expressed by their names, and not by detailing the manner of making them, as though they were new and unknown substances.

In the first trials that are made by persons unaccustomed to chemical operation, they must not expect much precision of result. Many difficulties will be met with; but in overcoming them, the most skilful kind of practical knowledge will be obtained; and nothing is so instructive in experimental science, as the detection of one's own mistakes.

The practical Chemist ought to be well grounded in general chemical information; and there is no better mode of gaining it, than that of attempting original investigations. In pursuing his experiments, he will continually be obliged to learn the properties of the substances he is employing or acting upon; and his theoretical ideas will be more valuable in being connected with practical operations, acquired for the purpose of discovery.

The greatest difficulty that occurs in the application or study of the generality of chemical Authors, is the loose language in which they indulge since the introduction of the new nomenclature. For the writers, seeming not to be aware of the names of that nomenclature being, in fact, those of a genus of chemical substances, and requiring specific distinctions to be added to them, in order to be applied to use, have employed them without any addition to denote several species of very different natures, yet all agreeing in the circumstance on which the generic name is found-

ed. In consequence of this looseness of expression in using generic terms instead of the trivial names of the several species included under them, or limiting their signification by specific differences, the chemists have sometimes inadvertently made the most glaring mistakes. To give a striking example from the most common substances; iron has been said to dissolve rapidly in sulphuric acid: which is true, if spirit of vitriol, or the sulphuric acid largely diluted with water, is used; but if oil of vitriol, or the purest and strongest sulphuric acid is used, it is necessary to boil the acid upon the metal.

Particular attention has been paid in this work to these circumstances, although only attainable in some cases by means which will appear to many as a needless prolixity of language.

*Brompton*, 1*st March*, 1828.

# PREFACE,

## BY THE AMERICAN EDITOR.

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At the commencement of the present year, the writer proposed to the publishers of this work to furnish for the press a small volume of essays on the bleaching of cotton and linen, calico printing, the manufacture of oil of vitriol, and bleaching powder, and several other of the more important branches of the Chemical Arts. He then learned that they were contemplating the republication of Gray's Operative Chemist, the general design of which was so similar to the more limited treatise proposed by him, the subjects so nearly connected, and in some instances identically the same, that the plan of incorporating the two works was suggested by the publishers, and, on mature consideration, adopted. Such was the origin of the present volume. The *Operative Chemist* was published in London in 1828, and is the first systematic treatise on the application of chemistry to the arts generally since the publication of *Aikin's Chemical Dictionary*, now about thirty years. The great discoveries in the science of chemistry, and consequent improvements in the Chemical Arts and Manufactures, within that period rendered a new work on the latter peculiarly desirable. The *Operative Chemist* was designed to exhibit a practical view of the numerous arts and manufactures dependent on chemical principles. It was

drawn up by one of the ablest operative chemists of Great Britain, who was practically conversant with most of the subjects treated of in his work, who enjoyed the facilities afforded by the Metropolis, of an extensive intercourse with the first scientific and practical men of the age, and of collecting and collating the numerous articles of practical intelligence scattered through the periodical journals of the present century. It remains to show in what respect the present volume differs from the work of Mr. Gray. With the exception of some few arts and processes not practised, and from local causes not likely to be practised, in the United States, the entire *practical* matter of the "*Operative Chemist*" has been preserved. Much, however, of the theoretical parts has been expunged, and its place supplied by other matter. The articles on Electricity and Galvanism, for instance, have been wholly omitted, as having not even the shadow of a claim to a place in a purely practical work on the arts. The beautiful discoveries, and apparatus, of Professor Hare should have a conspicuous place in every work which professes to treat of the general doctrines of chemistry; but they have not the remotest application to the practical processes of the arts. Nearly the same thing may be said of the articles on the compound blow-pipe, on burning-glasses and lenses, on light and many others, having reference merely to the principles of the science which, however interesting to the student of chemistry, are of little utility in the workshop, and may be found more fully treated of in almost every elementary work on the science generally;—they are, therefore, likewise omitted. The name of Mr. Gray's work has been exchanged for one, which accords better with its real objects and design, and particularly

with the contributions by the writer, which are exclusively of a practical nature, and for the most part contain the results of actual observation on the most extensive scale of manufacture. The additions by the writer are designated "*Operative Chemist*," by brackets. His steady purpose, both in abridging the original work, and in the contribution of new matter, has been to increase the practical value of the volume to the American manufacturer and operative chemist. How far he may have succeeded in that desirable object, a discerning public will judge.

A. L. PORTER.

*Dover, N. H., September 8th,* 1830.

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# CHEMISTRY

## APPLIED TO THE ARTS.

The philosophical chemists have gradually reduced the quantity of material upon which they operate to such minuteness, that they are enabled, in most cases, to do without furnaces, or any laboratory, but an ordinary library table: real practical chemists, however, find it necessary, even for the purpose of experiment only, to operate upon a larger scale; and to devote a room or building for the performance of their processes, that is known by the technical appellation of a laboratory.

The larger laboratories, or workshops, which are used only in particular branches of business, and the necessary apparatus attached to them, will be considered under the several substances which are prepared in them. Besides the workshop, every operative chemist ought to devote some part of his premises as a small general elaboratory, fitted up with such furnaces and other apparatus as may enable him to make any experiment seemingly applicable to the improvement of his manufacturing processes without loss of time, and immediately upon its conception. For want of this immediate appeal to experiment, many excellent thoughts have been lost to the manufacturing chemist.

It may be thought unnecessary for the experimental laboratory, here recommended to the operative chemist, to contain any other than his ordinary apparatus upon a smaller scale, on the ground that the metallurgist can have no occasion for the copper still boilers and copper pans of the pharmaceutical operator; nor the latter have any occasion for the wind and blast furnaces of the metallurgist. But although this is in some measure true, yet it is certain that the experimental laboratory ought to be furnished on the most general principles.

In many books of chemistry there are given very minute directions respecting the building and furnishing an experiment allaboratory, founded evidently on the idea that the chemist has sufficient space and command of money to do as he pleases in this respect. On these minute directions Dr. Ber-

kenhout pleasantly observes, that surely a chemist does not need to be informed that, in furnishing his elaboratory, he must not forget a nail upon which he may hang his hat, or a towel to wipe his hands.

As the object of the operative chemist is to apply to use the alterations that take place in bodies by the action of heat and cold upon them, and the combinations or separations that occur in their admixture with one another; therefore heat, whether it be a peculiar species of matter, or a peculiar kind of motion excited amongst the particles of bodies, is of the greatest importance in the practice of this art, and the modes of administering must be first considered. Of course, the furnaces for exposing the bodies, operated upon to the action of heat, are the principal part of the apparatus required by an operative chemist; and these are constructed differently, according to the nature of the fuel used in the country.

Where charcoal can be used without much increase of expense, it should always be preferred, on account of its being so much more manageable than any other species of fuel; and to attain this advantage it will frequently be preferable to make the experiments upon a small quantity of materials rather than forego its use; but in most parts of this country pitcoal and coke, from their cheapness, are the ordinary fuel burned in furnaces of all kinds.

Dr. Thomas Thomson, of Glasgow, has made a minute analysis of the different kinds of coals used in that manufacturing town; but these analyses are of little use to practical men. They serve to display the abilities of the operator in analysis, to ascertain the place of the substance in the theoretical system that is in fashion at the time; but for practical purposes, the relative heating powers of the several species of fuel are the thing that is required, in order that by combining this with their respective prices, their relative value may be discovered.

## THE RELATIVE VALUE OF FUEL.

Whatever kind of fuel it may be considered best to employ, it is extremely desirable that it should be as dry as possible, otherwise a great part of the heat it contains will be lost in converting the water in the fuel into vapour, which of course escapes up the chimney without producing any useful effect.

Fuel is often unnecessarily exposed to the weather, or put in wet places; and the injurious effect of introducing damp into a close fire-place is never considered.

## *Pit-Coals.*

There is considerable difference between the pit-coals; and it has perhaps been too little attended to by those who are the chief consumers of this expensive article. The subject has not even been studied with much attention, except so far as relates to the production of gas; and the facts that have been established by these researches are not very useful in other applications of fuel.

Caking coal, also called binding coal, crozzling coal, is obtained in great abundance from the extensive coal-fields in Northumberland and Durham; and is that which is sold in the London market as Newcastle coal.

When heated, this coal breaks asunder into small pieces; and the heat being raised to a certain degree, the pieces cohere, and form a solid mass, from which property it is called caking-coal. It lights easily, and burns with a lively yellow flame. It requires to be frequently stirred or broken up, particularly when it cakes very hard; but different varieties differ considerably in this property. Of the Newcastle coals, the best Wall's End make a brilliant and pleasing fire, burn away quickly, and do not cake hard, hence it is preferred for heating rooms; but the Tanfield Moor burn slowly, cake very hard, and afford a strong and long-continued heat, and is used in furnaces and forges. The other varieties are of an intermediate character.

Caking coal gives out a great quantity of heat, and, with attention, burns a long time; consequently, where it can be procured at a reasonable price, it is commonly preferred.

From the trials of Mr. Watt, it appears that a bushel of Newcastle coals, which weigh, on an average, eighty-four pounds, will convert from eight to twelve cubic feet of water into steam, from the mean temperature of the atmosphere; and that a bushel of Swansea coal will produce an equal effect.

Dr. Black states to the effect, that 7 pounds .91 of the best Newcastle-coal will convert one cubic foot of water into steam, capable of supporting the mean pressure of the atmosphere.

In some experiments tried by Messrs. Parkes, it appears, that by their improved method of constructing boilers, an effect was obtained, equivalent to converting one cubic foot of water into steam from the mean temperature, with 7 pounds .45 of coal, in the case where the greatest effect was produced; but at a mean, 8 pounds .15 of coal were necessary to produce the same effect; which is only one quarter of a pound less than the mean of Mr. Watt. From a mean of several experiments, Smeaton makes it require 11 pounds .4 of coal to produce the same effect; but the kind of coal is not described.

Mr. Tredgold found that after the brick-work, &c. of the boiler of a steam-engine was warmed, a little less than one pound of Wall's-End coals would make a cubic foot of water boil, from the mean temperature of fifty-two degrees. To produce the same effect with inferior coals, a stronger draught, and more time and attention, was necessary.

### *Splint-Coal,*

Or hard coal, called slaty cannel coal by Kirwan, is esteemed equally valuable, for many purposes, as the Newcastle caking coal. It is obtained near Glasgow, in Ayrshire, Scotland, and in several of the English and Welsh coal-fields.

A greater heat is necessary to make it kindle than is required for caking-coal; and consequently it is not so well adapted for a small fire; but a large body of splint coal makes a strong and lasting fire. It does not produce so much flame, nor so much smoke, as caking coal, and does not agglutinate or bind together.

The splint coal of Scotland was considered by Smeaton to be equal to Newcastle coal for steam-engines.

### *Cherry-Coal,*

Or soft coal, constitutes, says Dr. Thomson, the greater part of the upper seams of coal in the Glasgow coal-fields; and it is also abundant in Fifeshire. He considers the Staffordshire coal to be of the same species; and the Edinburgh as intermediate between it and splint-coal.

It readily catches fire, and burns with a clear yellow flame, giving out much heat; and the flame continues till nearly the whole of the coal be consumed. It burns away more rapidly than either caking or splint coal, and leaves a white ash. For most purposes it is less economical. It is easily distinguished from caking coal, by its not melting or becoming soft when heated. It makes a more agreeable fire, and does not require to be stirred. It requires care and management in an open grate, even to burn the small fragments which are made in breaking up the pieces to a fit size for the fire. Hence the small coals are often mixed with clay and made into balls. When these balls are dry, they make an excellent addition to the fuel for an open fire, producing a very durable heat.

Mr. Watt states that one hundred weight of good Wednesbury coal will produce the same effect as one bushel of Newcastle coal.

### *Wood.*

In some places wood is used for fuel; its effect in producing heat is found to depend considerably on its state of dryness.

Several experiments, made by Count Rumford, show the effect of dry wood to be much greater than that of unseasoned. Unseasoned wood contains about one third of its weight of water. The kind of wood is also a cause of some difference; from the experiments of Count Rumford, lime-tree wood gives out most heat in burning.

With his improved boilers Count Rumford made 20 pounds .10 of ice-cold water boil with one pound of dry pine wood. The same weight of pine wood unseasoned, would produce less effect by one-seventh. Beech wood afforded much less heat than pine; for one pound of dry beech made 14 pounds .33 of ice-cold water boil. A cubic foot of dry beech weighs about forty-four pounds.

According to Fossombroni, wood produces heat enough in its combustion to evaporate twice its weight of water, or to prepare two-thirds of its weight of salt. Count Rumford's trials make the effect of wood about one-third more, which may fairly be attributed to his superior skill.

### *Peat,*

Considered only as a fuel, may be divided into two kinds. The first is compact and heavy, of a brownish black colour, and with scarcely any vestiges of its vegetable origin remaining. This is the best kind. When it is once lighted it preserves fire along time.

The second kind is light and spongy, of a brown colour, and seems to be a mass of dead plants and roots which have undergone very little change; it inflames readily, and is quickly consumed.

Peat gives out an odour, while it is burning, which is disagreeable to those who are not accustomed to it. It affords a mild and gentle heat; but is not a good kind of fuel for supplying furnaces for boilers; it is much better adapted for flues. It is of various qualities: some burn quickly with a bright flame; others burn slowly, and, according to Clément and Desormes, afford one-fifth of the heat that would be given out by an equal weight of charcoal. This nearly coincides with the ratio given by Blavier and Miché.

The weight of a cubic foot varies from forty-four to seventy pounds; and the dense varieties afford about forty per cent. of charcoal; the other varieties nearly in proportion to their density.

### *Charcoal.*

Mr. Dalton, by heating water, obtained a result equivalent to melting forty pounds of ice with one pound of charcoal.

But Dr. Crawford's experiments give sixty-nine pounds of ice melted by one pound of charcoal. Lavoisier's give ninety-five pounds and a half; Clément and Desormes ninety-five pounds, and Hassenfratz's trials, on various kinds, give a mean of ninety-two pounds of ice melted by one pound of charcoal; his highest result being ninety-six pounds, and lowest one seventy-four pounds. Mr. Tredgold considers forty-seven pounds of ice melted by one pound of charcoal as the real average effect of that fuel. A cubic foot of charcoal weighs about fifteen pounds.

### *Coke.*

Lavoisier makes the quantity of coal to be that of coke as 605 is to 552 when the same effect is produced; and in addition to this increased power of giving out heat, it must also be considered that coke gives out no smoke in burning: whence it should always be used in furnaces seated in towns, in order to prevent any annoyance to the neighbours.

The present prevalent use of gas, for lighting towns and even houses, has brought a considerable quantity of *gas coke* into the market, which does well enough for heating rooms, but is far inferior to the stifled coke in its heating power, so that smiths and iron-founders invariably use the latter kind, and when a great heat is required, the chemist should follow their example.

Coke has been tried against wood in Paris for warming the Opera-House. Fifty-eight pounds of coke, costing there about 1*s.* 3*d.*, produced the same effect as 160 pounds of wood, costing there about 2*s.* 6*d.*

### *Charred Peat.*

According to Messrs. Blavier and Miché it requires 1666 pounds of charred peat to produce the same effect as 740 pounds of common charcoal.

The charred peat, made by stifling, is superior, in its power of producing heat, to that made by distillation. Unfortunately the stifled charred peat is a kind of pyrophorus, which takes fire if it becomes accidentally wetted, or even in moist weather. In consequence of this property several accidents have happened by the rain finding its way into places where it is kept; it is on this account forbidden, by the laws of some countries, to be kept in towns.

Therefore the Dutch, who burn this fuel not only in their houses, but even in pans under their feet while they are at church in winter, are in the habit of charring it at home as it is wanted. It is first burnt in the kitchen, and when they find it is red hot quite through, they then take it off the fire, put it

in a close earthen or copper pot, and cover it down with a wet woollen or linen cloth, and by the air being excluded the fire is soon extinguished, and when it is cold it will resemble charcoal, except being covered with white ashes, and will, if properly charred, burn with scarce any smoke, and very little of the suffocating quality which charcoal has. This it is that makes the charred peat so proper for green houses, for charcoal burnt in them is very prejudicial to the plants, and often fatal to the person who attends them.

[The intelligent author has here certainly fallen into a popular error in regard to the true cause of the suffocating quality of burning charcoal. The product of the combustion of charcoal must be essentially the same as from charred peat: the combustible part of both is little else than pure carbon, and the products of their combustion are of course pure carbonic acid. The popular notion is, that the unpleasant odour exhaled from burning charcoal, which has for some time been exposed to a damp atmosphere, and particularly when first ignited, is the suffocating principle: hence the common impression that ignited charcoal taken from a common fire may be burned with impunity in an unventilated room, and that charred peat, which does not exhale the peculiar odour of charcoal, is a safer and less objectionable fuel under the same circumstances. Many lives are annually sacrificed from this erroneous notion. The only true ground of preference of charred peat for burning in green houses is the slow and gradual manner in which it consumes. Charcoal, in this respect, is much less manageable. It is the sudden and unequal heats from charcoal, rather than any essential difference in the product, that renders its use so objectionable.]

The usual method of burning this peat in Holland, especially by the poor, is in cast iron-kettles, and for boiling any thing over it this way saves half the fire it would otherwise take if burnt on a hearth, or in a grate, by the side of the pot reflecting the heat.

[The small Philadelphia furnaces, fabricated from the South Amboy clay of New Jersey, now in general use in our Atlantic cities, are admirably calculated to secure an economical expenditure of heat in the combustion of charcoal for culinary purposes, and for a similar reason. But they ought never to be used in an unventilated room.]

Adjoining to many of the capital towns in Holland there are a great number of small gardens with little summer houses, most of which are built with wood. Near Rotterdam there are nearly a thousand of these gardens, and almost all of them have some orange trees in them. In the winter they are preserved from the intense frosts, which generally last there for nearly

three months, by means of this charred peat, the natural firing of that country, which is burnt in an earthen pan, or cast iron pot, in these little summer houses.

A collected view of the data from these experiments and comparisons is given by Mr. Tredgold. It is as follows:

| Kind of Fuel. | Fraction of a pound that will heat one cubic foot of water one degree of Fahrenheit's scale. | pounds of fuel that will convert one cubic foot of water into steam. |
|---|---|---|
| Newcastle, or caking Coal | 0·0075 | 8.40 |
| Splint Coal | 0·0075 | 8·40 |
| Staffordshire cherry Coal | 0·0100 | 11·20 |
| Wood, dry pine | 0·0172 | 19·25 |
| —— dry beech | 0·0242 | 27·00 |
| —— dry oak | 0·0265 | 30·00 |
| Peat, of good quality | 0·0475 | 53.60 |
| Charcoal | 0·0095 | 10·60 |
| Coke | 0·0069 | 7·70 |
| Charred Peat | 0·0205 | 23·00 |

It will appear, as Mr. Tredgold justly observes in his very excellent "Principles of Warming and Ventilating Public Buildings," that the utmost effect we can hope to gain in applying fuel must be less than double the measure of effect here given; and even to attain that effect all the caution of conducting a philosophical experiment must be continually employed, which will be found impracticable on a large scale, and altogether incompatible with the simple apparatus and small share of attention which can be devoted to this end in real business, although there are not wanting persons who promise four, six, and even ten times these effects.

### *Improvement of Fuel by Mixture.*

It is surprising that so few attempts should be made to improve the fires which are made in the open chimneys of elegant apartments by preparing the fuel; for, as Count Rumford observes, nothing surely was ever more dirty, inelegant, and disgusting than a common coal fire.

*Fire balls*, of the size of goose eggs, composed of coal and charcoal in powder, mixed up with a due proportion of wet clay, and well dried, would make a much more cleanly, and, in all respects, a pleasanter fire than can be made with crude coals; and it is believed would not be more expensive fuel. In Flanders, and in several parts of Germany, and particularly in the duchies of Juliers and Bergens, where coals are used as fuel, the coals are always prepared before they are used, by pounding them to a powder, and mixing them up with an

equal weight of clay, and a sufficient quantity of water to form the whole into a mass, which is kneaded together and formed into cakes; which cakes are afterwards well dried, and kept in a dry place for use. And it has been found, by long experience, that the expense attending this preparation is amply repaid by the improvement of the fuel. The coals thus mixed with clay not only burn longer, but give much more heat than when they are burnt in their crude state.

It will doubtless appear extraordinary to those who have not considered the subject with some attention, that the quantity of heat produced in the combustion of any given quantity of coal should be increased by mixing the coals with clay, which is certainly an incombustible body; but the fact is certain.

In composing fire balls, it is probable that a certain proportion of chaff, of straw cut very fine, or even of saw-dust, might be employed with great advantage. It is wished that those who have leisure would turn their thoughts to this subject; for it is conceived that very important improvements would result from a thorough investigation of it.

For the purpose of lighting a fire speedily, *kindling balls*, composed of equal parts of coal, charcoal, and clay, the two former reduced to a fine powder, well mixed, and kneaded together with the clay moistened with water, and then formed into balls of the size of hen's eggs, and thoroughly dried, might be used with great advantage instead of wood.

These kindling balls may be made so inflammable as to take fire in an instant, and with the smallest spark, by dipping them in a solution of nitre, and then drying them again; and they would neither be expensive nor liable to spoil by long keeping. Perhaps a quantity of pure charcoal, reduced to very fine powder, and mixed with the solution of nitre in which they are dipped, would render them still more inflammable.

[The foregoing meagre account of the relative value of several varieties of fuel, as determined by the heat produced in combustion, comprises about all the information which the labours of Crawford, Lavoisier, Rumford, Watt, Dalton, Clement, Desormes, and other philosophers, have shed upon the subject previous to the publication of Mr. Bull of Philadelphia, entitled "Experiments to Determine the Comparative Value of the Principal Varieties of Fuel used in the United States and in Europe," read before the American Philosophical Society of Philadelphia, in April, 1826. This is by far the most extended, systematic, and successful, effort yet made in this interesting field of experimental inquiry. I am indebted to the politeness of Mr. Bull for permission to transcribe the tabular results of his experiments, and such other portions of his interesting paper as more immediately comports with the practical character and design of this work; but would earnestly recom-

mend the perusal of the whole paper to every scientific manufacturer, or artisan, whose processes involve any considerable consumption of fuel, as well as to enlightened readers of every class; for no subject is more generally interesting in our cold climate than the most economical means of producing artificial heat.

The general principle on which Mr. Bull's experiments were conducted, for determining the comparative heat evolved in the combustion of the different varieties of fuel operated on, was to burn them in a close room, and note the time that the combustion of a given weight of each would sustain the air of the room at a temperature of 10° above the surrounding medium. To obviate the influence which the ordinary atmospheric changes of temperature and the winds would produce on the results, by furnishing a surrounding "refriguating medium of inconstant power," the room in which the experiments were performed was surrounded by double walls, and the intermediate spacesustained by artificial heat during the experiments, at a uniform temperature, and somewhat higher than the greatest natural temperature of the external atmosphere. The actual temperature of the inner and the outer rooms, during the experiment, was determined by common mercurial thermometers suspended in each, and the difference of temperature by Leslie's differential thermometer, the horizontal part of which traversed the inner wall, or partition, leaving a bulb and upright stem on each side. The combustion was effected in a small upright cylindrical stove, furnished with forty-two feet of sheet iron pipe of two inches diameter, having in it several convolutions before it left the room. So completely was the heat generated in the process of combustion dissipated by the pipe, and emitted into the room, that a thermometer, the bulb of which was inserted in the pipe just before it entered the chimney, indicated the same temperature as the one which hung in the room. As the conducting power of air, in relation to caloric, is influenced by its hygrometric state, care was taken to preserve it in a uniform condition in this respect. All the varieties of fuel operated on were dried previous to combustion, at a temperature of 250°, Fahrenheit. Their solid contents were determined in the usual method for irregular bodies, by the volume of water, which a given volume by the usual admeasurement displaces, and the specific gravities by the hydrostatic balance. In the latter case, porous substances, which expand by the absorption of water, as the wood, were previously covered with a varnish having exactly the same specific gravity as water; in short, no precaution seems to have been omitted by this laborious and able experimenter, to guard against every source of error, both in the construction of his apparatus, and in the general conduct of his inquiries. The following table exhibits the results of his experiments on sixty-six varieties of fuel.

| Common Names of Woods and Coals. | Botanical Names. | Specific Gravities of dry Wood. | Avoirdu pounds of Wood in on |
|---|---|---|---|
| White Ash, . . . | *Fraxinus americana,* . | .772 | 345 |
| Apple Tree, . . . | *Pyrus malus,* . . . | .697 | 311 |
| White Beech, . . | *Fagus sylvestris,* . . | .724 | 323 |
| Black Birch, . . . | *Betula lenta,* . . . | .697 | 311 |
| White Birch, . . . | *Betula populifolia,* . | .530 | 236 |
| Butter-nut, . . . | *Juglans cathartica,* . | .567 | 253 |
| Red Cedar, . . . | *Juniperus virginiana,* | .565 | 252 |
| American Chesnut, . | *Castanea vesca,* . . | .522 | 233 |
| Wild Cherry, . . . | *Cerasus virginiana,* . | .597 | 266 |
| Dog Wood, . . . . | *Cornus florida,* . . . | .815 | 364 |
| White Elm, . . . | *Ulmus americana,* . . | .580 | 259 |
| Sour Gum, . . . . | *Nyssa sylvatica,* . . | .703 | 314 |
| Sweet Gum, . . . | *Liquidumbar styraciflua,* | .634 | 283 |
| Shell-bark Hickory, | *Juglans squamosa,* . | 1.000 | 446 |
| Pig-nut Hickory, . | *Juglans porcina,* . . | .949 | 424 |
| Red-heart Hickory, | *Juglans laciniata?* . . | .829 | 370 |
| Witch-Hazel, . . | *Hamamelis virginica,* . | .784 | 350 |
| American Holly, . | *Ilex opaca,* . . . . | .602 | 269 |
| American Hornbeam, | *Carpinus americana,* . | .720 | 321 |
| Mountain Laurel, . | *Kalmia latifolia,* . . | .663 | 296 |
| Hard Maple, . . . | *Acer saccharinum,* . . | .644 | 287 |
| Soft Maple, . . . | *Acer rubrum,* . . . | .597 | 266 |
| Large Magnolia, . | *Magnolia grandiflora,* | .605 | 270 |
| Chesnut White Oak, | *Quercus prinus palustris,* | .885 | 395 |
| White Oak, . . . | *Quercus alba,* . . . | .855 | 382 |
| Shell-bark White Oak, | *Quercus obtusiloba?* . | .775 | 346 |
| Barren Scrub Oak, . | *Quercus catesbæi,* . . | .747 | 333 |
| Pin Oak, . . . . | *Quercus palustris,* . . | .747 | 333 |
| Scrub Black Oak, . | *Quercus banisteri,* . . | .728 | 325 |
| Red Oak, . . . . | *Quercus rubra,* . . . | .728 | 325 |
| Barren Oak, . . . | *Quercus ferruginea,* . | .694 | 310 |
| Rock Chesnut Oak, . | *Quercus prinus monticola,* | .678 | 303 |
| Yellow Oak, . . . | *Quercus prinus acuminata,* | .653 | 291 |
| Spanish Oak, . . . | *Quercus falcata,* . . | .548 | 244 |
| Persimon, . . . . | *Diospyros virginiana,* | .711 | 317 |

| Product of Charcoal from 100 parts of dry Wood, by weight. | Specific Gravities of dry Coal. | Pounds of dry Coal in one bushel. | Pounds of Charcoal from one cord of dry Wood. | Bushels of Charcoal from one cord of dry Wood. | Time 10° of Heat were maintained in the room, by the combustion of one pound of each article. | Value of specified quantities of each article, compared with Shell-bark Hickory as the Standard. |
|---|---|---|---|---|---|---|
| | | | | | H. M. | Cord. |
| 25.74 | .547 | 28.78 | 888 | 31 | 6 40 | 77 |
| 25 | .445 | 23.41 | 779 | 33 | 6 40 | 70 |
| 19.62 | .518 | 27.26 | 635 | 23 | 6 | 65 |
| 19.40 | .428 | 22.52 | 604 | 27 | 6 | 63 |
| 19 | .364 | 19.15 | 450 | 24 | 6 | 48 |
| 20.79 | .237 | 12.47 | 527 | 42 | 6 | 51 |
| 24.72 | .238 | 12.52 | 624 | 50 | 6 40 | 56 |
| 25.29 | .379 | 19.94 | 590 | 30 | 6 40 | 52 |
| 21.70 | .411 | 21.63 | 579 | 27 | 6 10 | 55 |
| 21 | .550 | 28.94 | 765 | 26 | 6 10 | 75 |
| 24.85 | .357 | 18.79 | 644 | 34 | 6 40 | 58 |
| 22.16 | .400 | 21.05 | 696 | 33 | 6 20 | 67 |
| 19.69 | .413 | 21.73 | 558 | 26 | 6 | 57 |
| 26.22 | .625 | 32.89 | 1172 | 36 | 6 40 | 100 |
| 25.22 | .637 | 33.52 | 1070 | 32 | 6 40 | 95 |
| 22.90 | .509 | 26.78 | 848 | 32 | 6 30 | 81 |
| 21.40 | .368 | 19.36 | 750 | 39 | 6 10 | 72 |
| 22.77 | .374 | 19.68 | 613 | 31 | 6 20 | 57 |
| 19 | .455 | 23.94 | 611 | 25 | 6 | 65 |
| 24.02 | .457 | 24.05 | 712 | 30 | 6 40 | 66 |
| 21.43 | .431 | 22.68 | 617 | 27 | 6 10 | 60 |
| 20.64 | .370 | 19.47 | 551 | 28 | 6 | 54 |
| 21.59 | .406 | 21.36 | 584 | 27 | 6 10 | 56 |
| 22.76 | .481 | 25.31 | 900 | 36 | 6 30 | 86 |
| 21.62 | .401 | 21.10 | 826 | 39 | 6 20 | 81 |
| 21.50 | .437 | 22.99 | 745 | 32 | 6 20 | 74 |
| 23.17 | .392 | 20.63 | 774 | 38 | 6 30 | 73 |
| 22.22 | .436 | 22.94 | 742 | 32 | 6 20 | 71 |
| 23.80 | .387 | 20.36 | 774 | 38 | 6 30 | 71 |
| 22.43 | .400 | 21.05 | 630 | 30 | 6 20 | 69 |
| 22.37 | .447 | 23.52 | 694 | 29 | 6 20 | 66 |
| 20.86 | .436 | 22.94 | 632 | 28 | 6 | 61 |
| 21.60 | .295 | 15.52 | 631 | 41 | 6 10 | 60 |
| 22.95 | .362 | 19.05 | 562 | 30 | 6 20 | 52 |
| 23.44 | .469 | 24.68 | 745 | 30 | 6 30 | 69 |

| Common Names of Woods and Coals. | Botanical Names. | Specific Gravities of dry Wood. | Avoirdupois pounds of Wood in one |
|---|---|---|---|
| Yellow Pine, (Soft,) | *Pinus mitis,* . . . | .551 | 2463 |
| Jersey Pine, . . . | *Pinus inops,* . . . | .478 | 2137 |
| Pitch Pine, . . . | *Pinus rigida,* . . . | .426 | 1904 |
| White Pine, . . . . | *Pinus strobus,* . . . | .418 | 1868 |
| Yellow Poplar, . . | *Lyriodendron tulipifera,* | .563 | 2516 |
| Lombardy Poplar, . | *Populus dilatata,* . . | .397 | 1774 |
| Sassafras, . . . . | *Laurus sassafras,* . . | .618 | 2762 |
| Wild Service, . . | *Aronia arborea,* . . | .887 | 3964 |
| Sycamore, . . . . | *Acer pseudo-platanus,* . | .535 | 2391 |
| Black Walnut, . . | *Juglans nigra,* . . . | .681 | 3044 |
| Swamp Whortle-berry, | *Vaccinium corymbosum,* | .752 | 3361 |
| Lehigh Coal, . . . | . . . . . | . . | . . |
| Lacawaxen Coal, . | . . . . . | . . | . . |
| Rhode-island Coal, . | . . . . . | . . | . . |
| Schuylkill Coal, . | . . . . . | . . | . . |
| Susquehanna Coal, . | . . . . . | . . | . . |
| Swatara Coal, . . | . . . . . | . . | . . |
| Worcester Coal, . . | . . . . . | . . | . . |
| Cannel Coal, . . . | . . . . . | . . | . . |
| Liverpool Coal, . . | . . . . . | . . | . . |
| Newcastle Coal, . | . . . . . | . . | . . |
| Scotch Coal, . . . | . . . . . | . . | . . |
| Karthaus Coal, . . | . . . . . | . . | . . |
| Richmond Coal, . . | . . . . . | . . | . . |
| Stony Creek Coal, . | . . . . . | . . | . . |
| Hickory Charcoal, . | . . . . . | . . | . . |
| Maple Charcoal, . | . . . . . | . . | . . |
| Oak Charcoal, . . | . . . . . | . . | . . |
| Pine Charcoal, . . | . . . . . | . . | . . |
| Coak, . . . . . | . . . . . | . . | . . |
| Composition of two parts Lehigh Coal, one Charcoal, and one Clay, by weight, | . . . . . | . . | . . |

| Product of Charcoal from 100 parts of dry Wood, by weight. | Specific Gravities of dry coal. | Pounds of dry coal in one bushel. | Pounds of Charcoal from one cord of dry Wood. | Bushels of Charcoal from one cord of dry Wood. | Time 10° of Heat were maintained in the room, by the combustion of one pound of each article. | Value of specified quantities of each article, compared with Shell-bark Hickory as the standard. |
|---|---|---|---|---|---|---|
| | | | | | H. M. | Cord. |
| 23.75 | .333 | 17.52 | 585 | 33 | 6 30 | 54 |
| 24.88 | .385 | 20.26 | 532 | 26 | 6 40 | 48 |
| 26.76 | .298 | 15.68 | 510 | 33 | 6 40 | 43 |
| 24.35 | .293 | 15.42 | 455 | 30 | 6 40 | 42 |
| 21.81 | .383 | 20.15 | 549 | 27 | 6 10 | 52 |
| 25 | .245 | 12.89 | 444 | 34 | 6 40 | 40 |
| 22.58 | .427 | 22.47 | 624 | 28 | 6 20 | 59 |
| 22.62 | .594 | 31.26 | 897 | 29 | 6 20 | 84 |
| 23.60 | .374 | 19.68 | 564 | 29 | 6 30 | 52 |
| 22.56 | .418 | 22 | 687 | 31 | 6 20 | 65 |
| 23.30 | .505 | 26.57 | 783 | 29 | 6 30 | 73 |
| | | | | | | Ton. |
| . . | 1.494 | 78.61 | . . | . . | 13 10 | 99 |
| . . | 1.400 | 73.67 | . . | . . | 13 10 | 99 |
| . . | 1.438 | 75.67 | . . | . . | 9 30 | 71 |
| . . | 1.453 | 76.46 | . . | . . | 13 40 | 103 |
| . . | 1.373 | 72.25 | . . | . . | 13 10 | 99 |
| . . | 1.459 | 76.77 | . . | . . | 11 20 | 85 |
| . . | 2.104 | 110.71 | . . | . . | 7 50 | 59 |
| | | | | | | 100 Bushels. |
| . . | 1.240 | 65.25 | . . | . . | 10 30 | 230 |
| . . | 1.331 | 70.04 | . . | . . | 9 10 | 215 |
| . . | 1.204 | 63.35 | . . | . . | 9 20 | 198 |
| . . | 1.140 | 59.99 | . . | . . | 9 30 | 191 |
| . . | 1.263 | 66.46 | . . | . . | 9 20 | 208 |
| . . | 1.246 | 65.56 | . . | . . | 9 20 | 205 |
| . . | 1.396 | 73.46 | . . | . . | 9 50 | 243 |
| . . | .625 | 32.89 | . . | . . | 15 | 166 |
| . . | .431 | 22.68 | . . | . . | 15 | 114 |
| . . | .401 | 21.10 | . . | . . | 15 | 106 |
| . . | .285 | 15 | . . | . . | 15 | 75 |
| . . | .557 | 29.31 | . . | . . | 12 50 | 126 |
| . . | . . | . . | . . | . . | 13 20 | |

On the first inspection of the foregoing table I was surprised, as I presume others have been, at the general aspect of the 10th column in relation to the wood. The difference in the heat produced by the combustion of equal weights of dry woods is much less than I had apprehended, and such as to induce a momentary suspicion of the general accuracy of the results. The extreme times in which given weights of forty-six varieties of dry woods sustained a temperature, in the inner room, of 10° above the surrounding medium, are only as 9 to 10. If we turn to the 5th column, we observe a remarkable coincidence between the weight of charcoal, which each variety of wood yields, and the heat produced by combustion. This correspondence is noticed by Mr. Bull. It is not exact, but sufficiently so to justify the inference, that the small difference in the actual value of fuel, as determined by the heat emitted on combustion, is mainly attributable to variations in the quantity of carbon they contain. As the results in these two columns were obtained by actual experiment, and by processes entirely dissimilar, the coincidence noticed affords a strong confirmation of the general correctness of both.

The eight first columns of figures, in the above general table, contain the results of actual experiments, for the details of which I must refer the reader to Mr. Bull's work. The last column is obtained by calculation. Mr. Bull found that shell-bark hickory has the greatest specific gravity of all the varieties of wood experimented on, (as indicated in the table;) and, as an equal weight of it was observed to maintain a given temperature in the room as long a time as any other, it follows that a cord of this wood would yield the greatest amount of heat in combustion: assuming, therefore, the specific gravity of shell-bark hickory to be 1.000, and its value as 100, the value of the other woods must be in the compound ratio of their respective specific gravities, and the time which a given weight was found to sustain the required temperature, and is given in decimal expressions of this last number. On this subject Mr. Bull observes, "that although shell bark hickory has been taken, for convenience, as the standard to construct the column of comparative values, the economist should take the cheapest article of fuel in the market, as his standard of comparison."

If we assume the average quantity of charcoal yielded by the dry woods to be 20 *per cent.* by weight, and the average time that a pound of dry wood sustained a temperature of 10° above the surrounding medium in Mr. Bull's Experiments, to be six hours (both of which terms are below the truth, but which sustain to each other about the ratio, which we observe between the 5th and 10th columns in his table,) it results that just 50 *per cent.* of the heat emitted in the combustion of dry wood is to

be attributed to the combustion of the carbon which it contains: for one pound of charcoal sustained the temperature of the room, at the required point, just two and a-half times as long as the assumed average time that a pound of wood would do, which yields 20 *per cent.* of charcoal, and $.20 \times 2.5 = .500$.

The following remarks of Mr. Bull are full of interest to the economist of fuel. "From experiments made to ascertain the weight of moisture absorbed by the different woods, which had previously been made perfectly dry, and afterwards exposed in a room in which no fire was made during a period of twelve months, the average absorption by weight, for this period, was found to be 10 *per cent.* in forty-six different woods, and 8 *per cent.* in the driest states of the atmosphere; and an unexpected coincidence was found to exist in the weight absorbed by forty-six pieces of charcoal, made from the same kinds of wood, and similarly exposed, the latter being also 8 *per cent.*

"The quantity of moisture absorbed by the woods individually was not found to diminish with their increase in density; whilst it was found that the green woods in drying uniformly lost less in weight in proportion to their greater density. Hickory wood, taken green, and made absolutely dry, experienced a diminution, in its weight, of 37½ *per cent.*, white oak 41 *per. cent.*, and soft maple 48 *per cent.* A cord of the latter will, therefore, weigh nearly twice as much when green as when dry.

"If we assume the mean quantity of moisture in the woods, when green, as 42 *per cent.*, the great disadvantage of attempting to burn wood in this state must be obvious; as in every 100 pounds of this compound of wood and water, 42 pounds of aqueous matter must be expelled from the wood, and as the capacity of water for absorbing heat is nearly as 4 to 1 when compared with air, and probably greater during its conversion into vapour, which must be effected before it can escape, the loss of heat must consequently be very great.

"The necessity of speaking thus theoretically, upon this point, is regretted; but it will be apparent that this question of loss cannot be solved by my apparatus, as the vapour would be condensed in the pipe of a stove, and the heat would thereby be imparted to the room, which, under ordinary circumstances, escapes into the chimney."

If we adopt the statement of Mr. Tredgold, that 8.40 pounds of Newcastle Coal will convert one cubic foot, or 62½ pounds, of water, into steam, under common pressure of the atmosphere, which is probably correct, Mr. Bull's table furnishes the remaining necessary *data* for a more accurate determination of the loss sustained in burning green wood. Take, for example, 100 pounds of green white oak, which Mr. Bull

found to contain 41 pounds of moisture: according to Mr. Tredgold, 41 pounds of water require 5.51 pounds of Newcastle Coal for conversion into vapour. Now we have the relative values of oak wood and Newcastle Coal, as it regards their power of producing heat, in the 10th column of Mr. Bull's table: 1 pound of white oak maintained 10° of heat in the room six hours and twenty minutes, and one pound of Newcastle Coal nine hours and twenty minutes. We have then this proportion; as 380′:560′:: 5.51 : 8.12 pounds of dry oak, consumed in converting 41 pounds of water into steam; or, in other words, 13¾ *per cent.* of the combustible matter of green oak is employed in boiling away its own water, and, in all ordinary cases, is a dead loss. It is true that arrangements might be made by a very protracted iron pipe, as in the stove used by Mr. Bull in his experiments, and other contrivances, for condensing the steam thus formed from green wood, and recovering both the latent and the sensible heat of the steam; but such an apparatus would be attended with too many inconveniences to be adopted in our dwelling-houses, and would be perfectly impracticable in large fires in the arts, where the flue is necessarily kept at a temperature above boiling water, and where, of course, the steam could not condense.

In the foregoing estimate of the loss of heat by the combustion of green wood, I have considered the subject in a theoretical point of view; or, at least, only in relation to those operations which have for their object the diffusion of heat in the air of apartments. But in most of the arts the object is the reverse of this,—to produce a strong and *circumscribed* heat. In these cases there is not only an entire loss of that portion of caloric which escapes in the steam from most fuel, (for it cannot be recovered, even if subsequently condensed, to any efficient purpose,) but if the temperature fall, in consequence of this loss of caloric in the steam, below the required point, there must be a total loss of the whole fuel. I suspect that it would be quite impossible for our glass manufacturers and iron founders to procure the intense heat required in their furnaces with the use of green wood. I have noticed at several glass-houses, and the practice is probably general, that the weather-seasoned pine wood is dried, or rather baked, by a stove heat, at a temperature that not unfrequently ignites it before it is used. I think it not unlikely that this practice might, in many instances, be profitably extended to the ordinary fuel (pine wood) used for steam boilers in our river boats; or, in other words, that a portion of the fuel might be economically expended in drying the remainder preparatory to use. Mr. Bull estimates the average quantity of moisture, in woods which have been weather-seasoned from eight to twelve months, at about 25 *per cent.*

of their weight. It may be objected to this suggestion, that although stove-drying may be indispensable where the attainment of a certain high degree of heat is absolutely necessary to the success of the process, yet where this necessity does not exist, the water may be as cheaply dissipated by the absorption of the caloric in the ordinary combustion, as by burning a portion of the fuel separately for that object. To this it may be replied, that the effective heat imparted to steam boilers is not, as is generally supposed, in a direct ratio to the quantity of caloric emitted by the burning fuel, but more nearly in proportion to the elevation of the temperature in the fire-place above that of the water within the boiler. The vapour formed by a fire that shall only elevate the temperature of the water to within a few degrees of the boiling point, say to 200°, bears a very small proportion to that which is produced at 212°; so that it is quite easy to burn a considerable quantity of fuel under a boiler to almost no practical effect. To pursue this subject into the causes of these results would lead to a theoretical disquisition on the laws which govern the communication of heat, foreign to the object of this work.

The great superiority assigned by Mr. Bull to the Lehigh and other anthracite coals, not only over wood but the best English coals, has also excited some doubt, and particularly with us at the north, of the accuracy of the comparison; but this, it may reasonably be supposed, is attributable to a mistake, against which Mr. Bull has warned us in his treatise, that of comparing his results with common experience derived from the very imperfect arrangements for the consumption of this fuel, both in the arts and in our dwellings. Its introduction is of too recent a date to have diffused correct information on this subject, and doubtless we have yet much to learn as to the best methods of applying it to many purposes in the arts.

"The composition balls of Lehigh coal, charcoal, and fire-clay," Mr. Bull observes, "were made for the purpose of ascertaining whether a very economical fuel might not be formed of the culm, or fine portions, of the two former, by combining them with the latter article, as they possess very little value: the same practice having been adopted with considerable advantage in various parts of Europe. The fire produced by these balls was found to be very clean and beautiful in its appearance. Its superior cleanliness is in consequence of the ashes being retained by the clay, and the balls were found to contain their original shape after they were deprived of the combustible materials. The beauty of the fire is enhanced by the shape and equality in the size of the balls, which during the combustion present uniform luminous faces. No difficulty was found in igniting, or perfectly consuming, the combusti-

ble materials, and the loss in heat, when compared with the combustion of the same quantity of each article in their usual states of aggregation, was found to be only three per cent." I think there must be an error, probably a typographical one, in carrying out the result of the combustion of this mixture in Mr. B's. table;—allowing the anthracite and charcoal to yield the same heat as assigned to them when burned separately in the aggregate form they should have sustained the same temperature only ten hours and twenty minutes.]

## FURNACES IN GENERAL.

The principal, and most critical parts of the apparatus subservient to chemistry, being the furnaces employed for the preparation of those substances which come within the chemical class, the structure of these is more complex, and the uses they are applied to of a more nice and difficult nature, by far, than any other of the operations regarding that art. It is, therefore, necessary that they should be well designed, and judiciously executed. Otherwise their defects greatly enhance the expense, and frustrate the intention of the operations they are to perform; besides their being extremely liable to become, in a very short time, out of repair, and uselessly ruinous.

It is also proper that careful and able men should be employed in the fabrication of furnaces; though such are rarely to be found among common workmen. But the most likely to succeed are those who have either been employed before in the same business, or have been accustomed to set coppers for household purposes. When the best qualified, however, are set to work, they should be continually superintended by the operator, or some person capable of judging, both of their adherence to the plan given, and general performance of the work. For if the parts of furnaces, that are exposed to much heat, be not made extremely compact, but are patched up of mortar and bricks that are not fitted in every part to each other, as bricklayers are very apt to do from the habits they acquire by being employed in coarser buildings, the mortar will very soon calcine, and shrink, in such faulty places, and make such vacuities and inlets to the air, as render the furnace incapable of doing properly its office, to the great delay, and sometimes destruction of the process.

The materials are the next object of attention; and they ought to be well chosen, and perfect of their kind. Common bricks, with good mortar, made with lime and coal ashes, well mixed and beaten together, will serve for those parts which are not

liable to be heated red hot: but where that degree of heat, or a greater, may happen, Windsor bricks, and Windsor loam, or Stourbridge clay;* and where the fire may be very violent, the composition called the fire lute, hereafter mentioned, should be used. And as the Windsor bricks are of a texture which admits of it, they should be so ground to fit each other, as to form one compact body with scarcely any interstices at all.

Particular care should be likewise taken in the drying of furnaces. For the best designed or constructed may be easily spoiled by any mismanagement in this point; and this is very frequently the case. Where the use of them is wanted, as generally happens, before they are ready, they are not allowed a proper time. The interior part should be, therefore, suffered to settle and dry, for some days, before the cavity be closed in by finishing the upper; and after that part also is become pretty firm, they should be gradually warmed by a small charcoal fire, made either in the body of the furnace itself, or in the ash-hole under it. After this has been some time continued, and the mortar appears hard in the inward surface, a coal or wood fire may be made, of a gentle degree at first, and increased slowly, as the smoking of the furnace may indicate to be proper. But the more leisurely this proceeds the more durable and perfect will be the furnace.

Notwithstanding the great importance of commodious furnaces to the practice of chemistry and pharmacy, the methods in general used for their construction are surprisingly defective. Several errors committed with regard to them are here hinted. and on what principle they may be avoided; the remedy, however, in each case, will be reserved, till the improved plan for the construction of the several particular kinds is given.

"The first and most obvious fault is the disposing the fire-place in the front of the furnace, instead of putting it under the centre of the pot intended to be heated. By which means, the fire exerts its greatest force on the column of brick over it, calcining and destroying all that part of the furnace, without an equivalent effect on what it is intended to act upon. This improper disposition of the fire may, however, be easily avoided; and a right situation substituted, if the worm flue, improperly used in common, be omitted, and the other methods followed, which are given in the particular plans. And as the inconveniences resulting from this error extend as well to the fire-places of stills and boilers, as of other furnaces, an undue consumption of fuel, and quick destruction of the furnace, being always disadvantageous, it will be found beneficial to endeavour to remove them in all cases, especially as it may be done without producing any other incommodious consequence, except where immensely large vessels are in use, which unavoidably require a support of brick work under them.

"Another great error in the building of furnaces, particularly those for pots or stills, is, as has been hinted, the carrying the fire round the vessel to be heat-

* The clay obtained at South Amboy, N. J. answers the best purpose for fire bricks of any that I have met with in this country, but is inferior, I believe, to the Stourbridge clay.—Am. Ed.

ed, in a vermicular flue, or worm, as it is commonly called; by which means the vessel intended to be heated, is much longer in attaining a due degree of heat. As the principal force of the fire is exercised upon that great mass of brick-work which forms the worm, and is brought into equal contiguity with the vessel itself, in respect to the fire, with indeed a much greater surface exposed to it; from whence it requires a proportionable quantity of fire to keep the whole in any stated degree of heat.

"Besides the great delay, therefore, in the beginning of the operation, which cannot proceed till the whole mass, that makes the worm, be brought to a certain heat, the due effect cannot be had, without the consuming a much greater proportion of fuel than if the heated vessel hung in the open furnace.

"But there is yet another momentous inconvenience, arising from furnaces of this kind of structure, where a strong heat is wanted; which is, that the brick-work of these worms is extremely subject to be damaged, and fall to pieces. From whence, the flue being choked up, and the draught obstructed, a necessity arises of taking down all that part, if not the whole of the furnace, and rebuilding it at a great expense, as there is no possibility of repairing it under these circumstances.

"An entire open cavity carried round the pot, still, &c. formed by raising the brick-work, at an equal distance, on every side, and closing it in where no farther heat is required, answers the end much better. It suffers the proper object to be immediately surrounded by the fire, and places it out of the contact of other bodies, so as to be capable of being independently heated; while the furnace itself is much less liable to be damaged, or can sustain a small degree of damage, without any material injury to its use; and even when it is injured, so as to require repairing, admits of it with greatly less trouble and expense, than when built in the other method."

## PRINCIPLES OF CONSTRUCTING FURNACES.

The importance of furnaces in the practice of chemistry is so great, that the principles on which they are to be constructed ought to be carefully studied, in order to be able to adapt them to the purpose the artist designs.

Furnaces consist of a variety of parts, namely; 1st, the twere, or entrance for air; 2d, a room to receive the ashes of the fuel; 3d, an ash-room entrance by which the ashes may be extracted; 4th, a grate to support the fuel; 5th, a fire-room to hold the burning-fuel; 6th, a feeding-door by which fresh fuel may be added as often as is necessary; 7th, a stoking-door by which the fuel is managed; 8th, the throat, or bridge, by which the flame and heated air are admitted into the laboratory or chamber of the furnace; 9th, the laboratory or chamber containing the vessels and materials to be acted upon by the fire; 10th, the entrance into or out of the chamber; 11th, the vent by which the flame and heated air passes out of the chamber into the flue of the chimney, and finally, 12th, the chimney to carry off the heated air and smoke into the atmosphere.

All these twelve parts are not to be found in every furnace, three of them only being essential to the very idea of a furnace; namely, the twere or entrance for air, the fire-room, and the vent.

### *The Twere.*

The twere, or entrance for air, is generally made to open into the ash-room, but sometimes into the fire-room itself. When it is intended to admit the atmospheric air by the unassisted pressure of the latter, as in what are called air furnaces, it should be made as far beneath the level of the grate as the situation will allow. In some cases it is made to open out of a deep vault, or long subterraneous passage, or a hole being cut in the wall of the laboratory, an iron pipe is laid down so as to allow a current of cool air to flow from the outside of the laboratory into the furnace: the outer mouth of this pipe is frequently made conical.

The entrance of the air, in air furnaces, should in all cases be regulated, or, at the least, be capable of being stopped altogether, whenever it is judged requisite. Various methods are used for this purpose. The oldest, and, when the twere is not too large, still the best, is merely to heap up ashes against the twere, and to regulate the opening by means of a poker or spatula: at present, an iron door is more generally used, which is opened more or less as occasion requires. Some chemists use a series of circular holes, having their diameters in geometric progression, 1, 2, 4, 8, 16, &c., with stoppers fitted to them, as Dr. Black in his original furnace; others use one or two slides moving in grooves, and there is now sold in London a circular slide invented by Count Rumford.

In general the entrance for air in air furnaces is made much too large, so that the velocity of the air being diminished, it becomes much heated in its passage, expands, and thus a less weight of it is presented to the fuel. The area of the entrance ought to be regulated by the sum of the areas left open between the bars of the grate, and its area should not exceed two-thirds of those open spaces, in order that the air may strike against the grate with some degree of force.

Blast furnaces are those in which a larger quantity of air is supplied, by means of mechanical contrivances, than would pass through the fire by the unassisted pressure of the atmosphere. The air is made to enter the furnace by means of one or more pipes leading from the bellows or other blowing machine. In the small blast furnaces used by experimentalists, assayers, and other metallurgic artists, the twere is made no larger than barely to admit the blast pipe, and the crevices, if any are left, are usually stopped with soft clay; but in the large blast furnaces of the iron works this is not the case, and it is said that even in small blast furnaces there is some advantage in not being solicitous about closing the space between the blast pipe and the sides of the twere.

### *The Ash-Room.*

In regard to the ash-room, no particular observations occur, except that in the small blast furnaces of the French experimental laboratories it is now divided horizontally in two parts by a plate of earthen ware pierced by a circular row of holes, the object of which is to equalize the blast of air, so that it may strike against all parts of the grate with equal force.

The ash-rooom is indeed frequently sunk into the ground in order that the other parts of the furnace may not be raised too high for the purposes for which they are designed, and hence is often called an *ash-pit*, although it may really be above the level of the ground. A proper ash-pit, if small, must have a sloping floor, that the ashes may be easier drawn out; or, if large, steps are made into it to allow the operator a free passage to the door. The cavity made by this slope, or the steps, is sometimes, as by the founders, covered over with an iron grating, or by a trap-door, with holes bored in it to admit the air. In this case, as the ash-room door could not be well got at, even if the furnace was provided with it, an iron plate, or loose board, may be used to cover more or less of the grating, or trap-door, and thus regulate the draught, or stop it entirely.

### *The Ash-Room Entrance.*

The ash-room entrance is generally united with the entrance for air in air furnaces; but it is far better to have them separate, and to keep this entrance constantly shut by a door; and this the more especially, because it will very frequently happen that the position of the one is unfavourable for the other. Count Rumford's circular slide is usually fixed in an iron door for this entrance.

### *The Grate.*

The grate is one of the most important parts of an air furnace. In small furnaces it is frequently of pig-iron, and cast in a single piece, but in the larger grates each bar is cast separate, and has a shoulder at each end, and sometimes when they are two feet or more in length they have also another shoulder in the middle, by which they are made to keep at a proper distance from each other. The bars are from one inch and a-half to three inches deep, according to their length, and about one inch thick: they are put in so as to rest loosely upon bearing bars, placed across the top of the ash-pit, that they may be taken out easily, and renewed if it be necessary.

In the furnaces intended for boiling water, or a similar heat, a distance of half an inch between the bars is sufficient. In

those for greater heats, as in distilling, with earthen retorts or iron cylinders, the distance should be about three-quarters of an inch, and in melting furnaces, a full inch.

When furnaces are used to heat steam boilers, brewers' coppers, stills for ardent spirits, or evaporating pans in salt works, alum works, or the like, the grates are usually made of greater extent, in order to expose a large surface of the heated fuel, even to the extent of four or six feet square, and it is computed, that with half inch spaces between the bars, each square foot of the grate will consume about eleven pounds of Newcastle coal every hour. Now, although these large grates are laid sloping down towards the back of the furnace, at an angle of twenty, or even thirty, degrees, or with a fall of from five to seven inches and a-quarter in each foot, yet there is a difficulty of spreading the coals equally over the surface of such large grates; and the coals also run into large masses of clinkers, which are very troublesome to extract out of the fire.

When the purposes for which a furnace is constructed are such that a small fire is required at one time, and the heat must be vehement at another, Dr. Bryan Higgins used loose iron bars, an inch square, instead of a grate. For a moderate fire, so many of these bars were placed upon the bearing bars fixed in the walls of the furnace, as to leave interstices of half an inch between them: when the fire required to be increased, one or two of the bars were withdrawn, and those left on the bearers arranged at equal distances by the poker. If by chance any accident happened which required the fire to be suddenly stopped, the whole of the bars being withdrawn, the fuel descended at once into the ash-room.

### *The Fire-Room.*

In respect to the fire-room, the principal care is to surround it with those substances which conduct heat the slowest, in order to prevent the fuel being expended in waste. The side walls should, therefore, be double, with a space of about two inches and a-half between them; the two walls being tied together, as the bricklayers express it, by bricks from space to space, and this may either be left empty or filled with ground charcoal or coke.

[Wood ashes are preferable for this purpose; its non-conducting powers are nearly equal to those of charcoal, and it is not liable to be burned out by exposure to the air through the chinks, which are constantly occurring in the walls of furnaces, which are subjected to high heats.]

The inner wall must be constructed of such bricks as will bear the action of fire without running into glass; and these

must be set in an argillaceous cement of a similar nature, and commonly called fire-lute.

The fire-rooms of portable furnaces, which in England are usually made of iron plate, are, in like manner, lined, next the iron, with charcoal powder made into a consistent mass with clay water, and next the fire, either with fire bricks, fire-lute, or a mixture of charcoal or coke powder, with any clay that will bear the fire. Sage has recommended asbestos ground and mixed into a paste, with the mucilage of gum tragacanth, for the composition of portable furnaces.

With a view to avoid both the inconveniences lately mentioned as incident to large grates, Mr. Losh, of Point Pleasant, Northumberland, in a patent which he took out in 1815, recommends for furnaces of the kind there mentioned, the use of two or more, even as far as six grates, with as many separate fire-rooms; and he avers that from his long experience in the management of a large chemical manufactory, that this plan is attended with a great saving of fuel, and the boiling, generation of steam, distillation, and evaporation, goes on in a more equable manner; and also that the manual labour of the stoker is considerably less when several small fires are used to heat these great pots, than when only a single immense fire is to be minded. To which there may also be added the facility of repairing the fire-places without stopping the operations.

There is another view with which two grates, and as many separate fire-rooms are constructed under large boilers. These furnaces require a copious supply of fuel, which is generally raw coal, and emits of course a large quantity of black smoke every time a fresh supply of coal is put upon the fire, to the great annoyance of the neighbourhood.

With a view to get rid of this inconvenience two plans have been adopted. Mr. Watt, in 1785, constructed a small second fire-room and grate between the principal fire-room and the chimney, in which he kept a small fire of cinders, coke, or or other clear burning fuel, in order that the smoke as it passed over this clear fire might be burned; but this plan has not been found to answer completely, as the necessary supply of air for the combustion of the smoke could not be supplied through this small secondary grate.

Lately, Mr. Newman has proposed another somewhat similar construction. He builds two fire-rooms and grates side by side, which communicate with each other; each of these fire-rooms has a vent into the chimney, which can be opened or stopped at pleasure. Supposing, then, a fire is made in both fire-rooms, and the vent belonging to the fire-room A is open, and that of B shut, the smoke generated on adding fresh fuel to B, will have to pass over the surface of the fire in A, and

thus be burned for the most part in its passage. The next parcel of fuel is to be supplied to the fire-room A, and for this purpose the vent of the fire-room B is to be first opened, then that of A closed, and lastly the fuel supplied; the smoke from which will then be obliged to pass over the surface of the fire in B. In this alternate mode the two fires are to be supplied, and the smoke from the one made to pass over the other.

### *Stoking Hole.*

A stoking hole is necessary in furnaces for lighting the fire, and extracting the clinkers that are formed. For the convenient performance of these purposes this hole must be on a level with the grate or nearly so; and if the grate is formed of loose bars, which are to be occasionally pulled out or put in, as a greater or less degree of heat is required, it should descend a little below the grate to give room for this purpose.

This hole is generally closed by an iron door, lined with clay or a piece of fire-stone. For the purpose of ascertaining when the fire wants stirring or replenishing, a hole, about an inch in diameter, and covered by a piece of iron, which hangs loose by a rivet above, is sometimes made in this door.

### *Feeding Hole.*

The feeding hole, by which fuel is supplied to the fire-room, is usually on the side a little above the height to which the fuel reaches, but sometimes on the top of the fire-room. It should be made large, that a considerable quantity of fuel may be added at once, and thus the frequent opening of this hole, and the consequent cooling of the interior of the furnace, be prevented.

This opening is very often closed by means of a door hung on hinges, or sliding up and down, being supported by a counter weight; sometimes a stopper is used, but these are apt to stick; the door or stopper is usually made of iron and lined with fire-lute, or in small furnaces the stoppers are made of clay.

Sometimes what is now called a *hopper* is used, which is made of cast-iron plates, and set rather sloping in the furnace. This being filled with coal has its outer end stopped up with small caking coal, and as the fuel in the fire-room is consumed that in the hopper is pushed in to supply its place; care being taken respecting the keeping of the outer end stopped by the small coal.

Even in this method of feeding the fire, cold air is necessarily admitted, and the interior of the furnace cooled in consequence; so that, although hot air be admitted into the chamber, yet the smoke will not take fire until sometime after the coals have been added.

To avoid this inconvenience close hoppers have been contrived with a moveable bottom, formed either of a sliding plate, or one moving on a hinge, and held up by a counter weight equal in effect to the weight of the coal contained at any one time in the hopper, which is closed at top by an iron lid shutting very close. This close hopper, being built in the furnace directly over the fire-room, or, at least, the front part of it, is filled with coal, the lid shut down, and when the fire wants replenishing, the bottom is opened, and the coal of course falls down on the fire, without the introduction of any cold air to cool the interior of the furnace.

When this mode of feeding is adopted, it will be adviseable, just before the letting fall of the fresh coal, to push that already in the furnace towards the back, by means of an iron hoe, as wide as the fire-room, and about four inches deep, with a long iron handle passing through a hole in the bottom of the stoking-door, and which hoe remains constantly in the furnace, being pulled up close to the stoking-door, before the fresh coal is let fall.

A feeding hole, distinct from the stoking hole, is seldom used in England, notwithstanding its advantages were set forth by Mr. Dossie, in his "Elaboratory laid Open," fifty years ago. He very justly observed, that if the fuel can only be thrown in at the stoking hole, there exists a necessity for having the area of the fire-place large, since otherwise a sufficient quantity of fuel cannot be made to lie upon it. For if the grate be small, the coals tumble out, whenever it is filled to any great height, every time the door is opened.

Now the disadvantages consequential to the having the fire-place too large are manifold. For if the space, occupied by the bars, be great, and the whole area they make, be covered with coals, the heat will be too strong on many occasions.

If the whole area be not covered, a false draught is made through the uncovered part, which greatly weakens both the degree and effect of the fire proportionably to the quantity of fuel. As the influx of the air will be the greatest through the naked part of the area, which much weakens the draught through the coals, at the same time, it greatly refrigerates both the furnace and its contents; so that not only a great waste of fuel is in such case made, but the latitude in the degree of heat, and means of accommodating it to the occasion, which are to be completely had in furnaces well constructed, are hereby greatly limited. This defect may, he observed, be remedied, by making a proper feeding hole, sloping slightly towards the fire, some inches above the surface of the fuel, when at the highest.

Through this hole the fire may be fed by a shovel of a fit size and figure, or stirred with a poker, properly bent, without

using the door for those purposes, which need, therefore, only be opened for the making or lighting the fire, or freeing the bars from the scoria or clinkers, when they are choked up with them.

This manner of feeding the fire will be found a very great convenience to those who are accustomed to it. As the effectual draught of the furnace may be thence greatly increased, the lighting the fire much facilitated, and the operator likewise enabled to have what body of fuel he pleases in the furnace, and to adequate the heat with certainty, to any occasion, without either being subject to have the fire extinguished, when it is kept low; or not to admit of being raised high, with the falling out of the coals, already in the furnace, every time he attempts to throw in a fresh supply.

When this device is used, the usual area of the bars may be diminished at least one half; and the consumption of fuel will be lessened much more than in that proportion, for the reasons before given. The operation will not be soon checked, on any neglect in keeping up the fire, which is liable to happen, when furnaces are built in the common way.

### *The Throat.*

In many furnaces there is no visible throat between the fire-room and chamber; the walls of the two rooms being continued in a line. In some, however, the separation is very distinct, and the throat is either a simple opening, the lower limit of which, when on the side, is usually called the bridge, or instead thereof, a number of small holes disposed, generally, in a quincuncial order, or chequer-ways, by which arrangement the distribution of the heat through the chamber is rendered more equal than when only a single opening is used. In this case, care must be taken that the sum of the area of these holes shall not exceed that of the free space between the bars of the grate, otherwise the desired equal distribution of the heat cannot be obtained.

### *The Chamber.*

The situation of the chamber varies much, and gives certain denominations to various furnaces. In some furnaces the chamber and fire-room are united; and even in this case there are several variations: for sometimes the substances to be acted upon are mixed with the fuel, and that either in alternate beds, one on the other, as in lime and brick-kilns, or the fuel and the other materials are thrown alternately in at the mouth of the furnace, as in the blast-furnaces in which iron ore is smelted. In other furnaces, the vessels containing the materials are either placed circularly round the fire next the well of the fire-

room, as in glass-house furnaces, and those in which spelter is distilled and brass made; or else the vessel is placed in the centre of the fire, and entirely surrounded with fuel on the top as well as on the sides, as in the furnaces of founders and casters of metals: this latter disposition has received, amongst practical writers, a peculiar denomination, namely, that of a wheel-fire, or ignis rotæ.

The chamber, when it forms a separate part from the fire-room, admits of three variations; for sometimes it is over the fire-room, sometimes on the side, and sometimes it is placed in the centre, and surrounded with several fire-rooms.

The chamber is placed over the fire-room in the furnaces used with pots, kettles, eommon stills, and the boilers for producing steam. These vessels in general hang down from the mouth of the ehamber, which is placed directly over the fire-room, and there is a sufficient space left between the vessel and the walls of the ehamber, to allow the free passage to the vent of the air that has passed through the fire. The breadth of this space is usually left to the judgment of the bricklayer; the horizontal area of it ought to be equal to that of the free space between the bars of the grate, which is the radix from whence all the proportions of the different parts of a furnace are to be ealculated. Hence, if it be required to determine the space to be left between the outside of a eylindrical pot, boiler, or still, and the wall of the furnace, first find the area of the horizontal circular section of the vessel, measured on the outside, by any of the methods in use for that purpose, (which may be seen in Mr. Nicholson's Operative Mechanic, page 694, or any treatise on Mensuration;) and to this area add that of the free space between the bars of the grate, the sum will be the area of the circle to be formed by the internal side of the wall; the diameter of which being found, the difference between this diameter and that of the vessel being halved, will be the breadth of the space to be left between the vessel and the wall of the furnace.

In these kinds of furnaces there is seldom any contraction, or throat, between the fire-room and the chamber in whieh the vessel hangs. Curaudau has proposed to throw an arch over the fire-room, with a circular opening in the centre, and affirms that by thus contracting the space to which the full force of the fire is first applied to the vessel, it produces a more powerful effect; but there also arises this inconvenience, that this part of the vessel is liable to be burnt out before the other parts, so that frequent renewals of the vessel are requisite. When indeed the vessel is very large, it requires to have its bottom supported by pillars of masonry, so disposed as to allow a free passage for the air that has passed through the fire to get to the vent.

Furnaces with ehambers over the fire-room are also used by

tobacco-pipe makers, and in the potteries: in these furnaces the roof of the fire-room is pierced with several holes, that the heat may be distributed as equally as possible through all the parts of the chamber.

In the furnaces used for roasting ore, and smelting them, as also in certain other operations, as in baking porcelain ware, the chamber is placed on one side of the fire-room. The communication in these furnaces is usually made by a single opening, but sometimes a series of holes are used. The larger furnaces used by the potters have a large central chamber, with four or six fire-rooms surrounding it, and opening into it by as many single openings. The metallurgists also sometimes use a central chamber with a fire-room at each end.

Many contrivances have been adopted for the purpose of introducing a supply of fresh air into the chambers of furnaces to consume the smoke, which is emitted in such quantities every time the fire is supplied with raw pit-coal. A direct entrance into the chamber has the disadvantage of cooling it considerably, and is therefore not adviseable in any circumstances, and in addition to this the smoke itself is not thoroughly consumed by this method.

Several patentees have made channels in the masonry of the furnace leading from the top of the ash-pit, near the grate, into the chamber; and some have furnished these channels with sliders. Others have made channels in the walls of the fire-room, opening at one end to the external air, and at the other into the chamber. The object of these patentees being to supply the fresh air in a heated state, that it may accend the smoke, and thus cause its consumption; but, as the furnace is always considerably cooled every time the door is opened to supply coal, the smoke is sometime before it will burn.

A still more powerful method of effecting this object has been lately proposed by Mr. Chapman, of Whitby. He causes the bars of the grate to be cast hollow, and when set in the furnace they open into two boxes, one placed in front and the other behind the grate. In the front box, which is of course directly under the stoking door, he has a register to admit more or less air at pleasure. The box behind the grate opens into an empty space, which is formed by making the bridge of the furnace double. Hence, when the register of the front box is open, there is a great draught of air through it, along the interior of the grate bars, thence into the space between the two walls of the bridge, and out of the slit at the top, where it comes in contact with the smoke, and as soon as the cooling of the furnace, by the opening of the door is overcome, causes it to inflame and become a sheet of bright fire under the bottom of the boiler; but when a close hopper is used, and the

introduction of cold air prevented, the smoke is entirely consumed from the first.

### *Opening into the Chamber.*

An opening into the chamber is required in almost every case. This is very commonly at the top, being a circular hole, in which the pot or still is hung. Sometimes it is on the side, as in those called English reverberating furnaces used for roasting and smelting ores, or in potters' kilns.

It is seldom that these openings into the chambers have doors adapted to them, as they are closed either by the vessel, as in the first case just mentioned, or they are filled up at the commencement of each operation by means of slight brickwork, which is removed when the operation is performed.

Sometimes the opening into the chamber is left open, and actually serves in some cases as a vent, the usual vent being stopped.

### *The Vent.*

The vent of the furnace has given rise to much difference of opinion as to the size it ought to have. Some make it large, to allow a freer passage for the burnt air into the chimney; others again small, that the heat may not be dissipated and carried up into the chimney in waste.

It is generally a single opening, but in porcelain furnaces, the manufacturers use a number of small openings instead of a single vent, with the view of assisting in the equal distribution of the heat throughout all parts of the chamber: and this practice should be adopted whenever this equal distribution is requisite. These artists are also careful that the sum of the areas of these holes should be exactly equal to that of the throats by which the flame and heated air enters into the chamber.

It seems, therefore, adviseable in all cases to make the vent or vents equal in area to that of the free space left between the bars of the grate.

The situation of the vent is usually at the top or back of the furnace; but there results a very great inconvenience from its being situated in the latter position; since, when the feeding or stoking-doors are opened to supply fresh fuel, or manage the fire, a strong indraught of cold air takes place, which rushes over the surface of the fire, and not only cools the whole interior of the furnace, and prevents the accension of the vapour from the raw fuel, thus causing the production of smoke and soot, but also cools the vessels and materials exposed to the action of the fire; and when the vessels are made of glass, pottery ware, or cast iron, frequently cracks them, unless they are defended by a thick coating of lute, which necessarily di-

minishes the heat that can be applied to the materials contained within them.

Mr. Losh, already mentioned as a considerable improver of the construction of furnaces, has therefore proposed to remove the vent to the front of the furnace, immediately over the feeding or stoking-door, and to conduct the burned air, through channels made in the masonry, into the flue of the chimney. A great advantage attends this construction, that when either of the entrances into the fire-room are opened, the indraught of air, instead of rushing over the surface of the burning fuel and striking against the vessels and materials, instantly passes up the vent, and does not enter at all into the interior of the furnace, whence this is much less cooled than in the furnaces of the usual construction.

As the entrance of air into the furnace is regulated by sliders and other contrivances, so in many furnaces, where this is neglected, its outlet is regulated by a damper or slider placed at the vent, by which its opening into the flue is altered at pleasure, and may be even stopped entirely: but it is far preferable always to have a door to the ash-room, or entrance for the air, and regulate the fire by it.

### *The Chimney or Flue.*

The chimney or flue is one of the most important parts of a furnace; and yet, in general, the least attended to; being usually made much too large in its horizontal area. By making it thus large, the draught through it is much diminished, and the soot collects and becomes troublesome. For when the sides of the flue contain a larger surface than can be duly heated, the necessary rarefaction of the air passing through it is destroyed. On this principle alone the draught of chimneys depends; and the cavity being too large proportionably to the current of air, the force of it is so diminished that the soot, instead of being blown out, gathers and rests on the sides till it obstructs the passage, and choking up the draught deadens the fire, especially at the first lighting of it; by which means the progress of the operation is sometimes greatly retarded. Instead, therefore, of the large proportion now made use of, if the chimney be intended for the use of one furnace only, an area equal to that of the free space between the bars of the grate is fully sufficient; and this may be increased in proportion where it is designed for a greater number.

The reverend Mr. T. Ridge has observed, that if a recess is left at the bottom of the flue, below where the vent of the fireplace enters it, the soot collects in this recess, and the fouling of the flue is proportionally prevented.

This recess or well might have an opening made into its low-

er part, which being opened occasionally, the soot might be extracted without the necessity of ascending the flue.

It is well known that when flues are carried horizontally, for the purpose of connecting a furnace with the upright shaft of a chimney, they fill very fast with soot, the draught through them can scarcely be maintained, and they are even apt to burst. On adding a recess on this principle to a horizontal flue, all the soot collected in the recess, and the flue was scarcely soiled.

A single flue is sometimes made to serve for several furnaces, which is advantageous when a number of furnaces are in constant action, so as to keep the mass of the chimney at a sufficient heat that the ascensional force of the air which has passed through the fire is not diminished by cooling. But unless this condition can be maintained, separate flues for each furnace will be most advantageous.

All the furnaces attached to a single flue, which are not in use, must be kept close shut up, or, at least, the dampers at their vents, if they have this apparatus, closed, otherwise a false draught will take place, and the cold air passing through them will cool the flue and diminish the heat of the furnaces that are in action.

The stability of the chimney against the action of the wind, when it stands separate from other buildings, requires that it should have a sufficient breadth of base. The calculations of Mr. Tredgold, in the supplement to the Encyclopædia Britannica, show that each side of a chimney, having a square basis, or the narrowest side if the basis be rectangular, should be at the least one foot in breadth for every ten feet in height; and the area of the flue ought not to exceed one-third of the area of the chimney.

The chimneys of our common domestic fire-places have their upper terminations enlarged, by the addition of a circular chimney-pot, which circumscribes their square flue. This enlargement is vulgarly, but erroneously, called a contraction, by those who look only to the external appearance without considering the greater thickness of the brick-work in respect to the sides of the pot; and is supposed to increase the draught of the flue.

With the same view, the chimneys in Venice are terminated by pots which are of a conical form, much wider at top than at bottom. From the experiments of Venturi, on the flowing of fluids through pipes, it would appear that this construction was preferable to our own chimney-pots, which are, on the contrary, rather narrower at top than at bottom. In describing the fourneau lithogeognosique of Dr. Macquer, an occasion will be had to relate an experiment of M. Guyton de Morveau, relating to adding a conical flue widening at top to this furnace.

When the chimney has attached to it furnaces which give a great heat, and of course have a strong draught, the ascensional force of the heated air will overcome the action of the wind, unless it blows a perfect storm. But in chimneys attached to furnaces of no powerful action, the wind frequently prevents the exit of the burned air, and thus diminishes the power of the fire. Hence all chimneys should have the top of their side walls sloped upwards from the outer surface to the inner, in order that the wind impinging on the top may be deflected upwards, and thus assist in drawing out the smoke and burned air.

The wall of chimneys is usually single; but when the air which passes up the flue is very hot, it has been found preferable to have the wall double, with an empty space left between the two, which are tied together from space to space by bricks passing from one to the other.

### *Velocity of the Draught.*

It might be supposed that the velocity of the draught through furnaces would long ere this have been reduced to calculation. Yet this is not the case, and the various measures of it by the several mathematicians who have investigated the subject, differ in an astonishing degree. They all, indeed, proceed upon the principle of the acceleration of velocity in falling bodies, and the usual theorems of hydrodynamics, but vary very considerably in the application of them.

The mathematical investigation of this apparently simple question may be divided into two classes. Most of them found their calculation on the compound ratio of the acceleration produced by the height of the chimney, and of difference in specific gravity between the external air of the atmosphere, and that in the flue of the chimney; and yet, even these do not agree in the results they obtain. On the other hand, Mr. Davis Gilbert, whose fame as a mathematician of the first rank is unimpeached, stands alone, as he grounds his calculation on the velocity with which atmospheric air rushes into a vacuum, or any medium of less density than itself.

They equally differ as to the place where the temperature of the heated air shall be taken to compare with that of the atmosphere: as the generality of writers take the temperature from the top of the chimney where the heated air rushes out into the atmosphere: while Mr. Davis Gilbert in this point varies from his brethren in choosing the temperature of the hottest part of the furnace for the ground-work of his calculation.

Taking, then, as an example, a furnace adapted for melting copper, with a chimney forty feet higher than the half, or average height of the entrance for air; the temperature of the hot-

test part of which is 1500 degrees of Fahrenheit, that of the air issuing from the chimney 123 degrees of Fahrenheit, and that of the external air forty degrees of the same scale. If we calculate the velocity according to the principles of M. Montgolfier, who is the first author who investigated the subject, as they are laid down by M. Payen in the Dictionnaire Technologique; namely, that the draught is equal to the velocity that would be acquired by a heavy body in falling through a space equal to the simple difference of the height of two similar columns of air standing upon the same base; the one of the air of the external atmosphere, and the other column of the air in the chimney, of the same height when hot, but reduced by cooling to the temperature of the atmosphere. Now, according to this hypothesis, the heated air will pass out of the chimney with a velocity of 10 feet .91 in each second of time.

Another mode of calculation has been given in the article Furnaces, in Rees' Cyclopædia, grounded upon Mr. Atwood's theorem, which leads the writer of that article to divide the difference of the specific gravity of the heated air and external air by their sum, the quotient multiplied by the velocity which a falling body would acquire, by falling freely through the height of the chimney, will, it is said, give the velocity of the current of air through the flue. But this velocity will, the writer thinks, be double the real velocity, on account of the retardation which the current experiences by the friction against the sides of the flue. Now, if this mode of calculation be pursued, the velocity of the air issuing from a furnace of this kind, will be 3 feet .88 in a second of time; so that if the half of this calculated velocity be taken for the real velocity, it will be 1 foot .94.

Passing over, for the present, the calculations of Mr. Davis Gilbert, as being founded upon a totally different hypothesis, the next author who has considered the subject is Mr. Sylvester, in the Annals of Philosophy, for June, 1822. He refers to Mr. Davis Gilbert's calculations, and conceives that the hypothesis on which he proceeds must be erroneous, because it produces for its result a velocity which far exceeds that of heavy bodies falling freely in a vacuum, whereas the resistance of the medium must produce some retardation of this velocity.

According to Mr. Sylvester, the velocity of the current of heated air will be equal to the difference between the specific gravity of the cold external, and heated internal air, divided by the specific gravity of the cold external air, and the quotient multiplied into the acceleration of velocity that would be acquired by a body falling the height of the chimney. Whence, on the preceding data, the velocity would be 7 feet .74.

In a recent work, written by Mr. Tredgold, he has given

very elaborate formulæ for calculating the draught of ventilating pipes, and the chimneys of furnaces. He assumes the force whereby the current ascends, to be equal to the height of the chimney, multiplied by the expansion the air suffers from the increased temperature to which it is subjected. And that the velocity is equal to the square root of sixty-four times the force; from which velocity, three-eighths, or even one-half, must be deducted on account of contractions, eddies, bends, and friction.

Now, on this hypothesis, the theoretical velocity of the current of air in the flue of a furnace of this kind will be equal to 18 feet .9; from whence, deducting one-half, the actual velocity is probably nine feet and a half.

Hence, although these mathematicians all proceed upon nearly the same theory, still great discrepancies exist in their results.

| | |
|---|---|
| According to Montgolfier's calculation, the velocity of the draught in every second of time, is - - | 13 ft. .91 |
| The writer in Rees' Cyclopædia - - - - | 1 .94 |
| Mr. Sylvester - - - - - - - - | 7 .73 |
| Mr. Tredgold - - - - - - - - | 9 .50 |

But these differences vanish entirely before the calculation of Mr. Davis Gilbert, in the Quarterly Journal of Sciences for April, 1822. According to this gentleman, the rarefaction or expansion of the air by the heat being ascertained, by raising the fraction $\frac{481}{480}$ to the power whose index expresses the difference of temperature, and the density or specific gravity of the burned air, as compared with that of the external atmosphere, which Mr. Gilbert states at 1.0874 to 1, the expansion divided by the specific gravity of the burned air, will show the specific gravity of the air within the chimney.

The tendency to ascend will, he says, be equal to the difference between this specific gravity and that of the atmosphere, multiplied by the quotient obtained by dividing the height of the chimney, by the height the atmosphere would have, if it were of uniform density throughout, which is assumed, by Mr. Gilbert, to be 26058 feet. The square root of this product is to be multiplied by the velocity with which the atmosphere would rush into a vacuum, namely, 1295 feet in a second of time; and the product divided by the square root of the specific gravity of the lighter air will give the velocity.

Now, according to this hypothesis, the velocity of the air passing through the above-mentioned furnace, would be no less than 225 feet .67 in a second of time; which being equivalent to 153 miles in an hour, is about five times the velocity of the wind in a full storm.

It would appear from the immense discrepance between these calculations of the velocity by the most eminent mathematicians,

that every attempt to reduce the question to mathematical calculation, has hitherto proved utterly abortive, and has left the subject in as much obscurity as ever. Thus much seems certain, that if any smoking or fuming body be held near the entrance of the air into a very powerful melting furnace, when in full heat, the velocity with which the smoke or fume is drawn into the furnace, seems by no means so rapid as might be expected on the calculation of Mr. Davis Gilbert.

Mr. Haycroft observes, that the heat in blast-furnaces does not increase merely in the ratio of the fuel consumed, but in some compound ratio: and that even in air-furnaces, those through which the greatest quantity of air passes in a given time, consume a proportionably less quantity of fuel to produce the same effect.

### *Annoyance of Smoke.*

It has been already seen how many contrivances have been had recourse to, for preventing the annoyance of the smoke so plentifully emitted by raw pit-coal, when suddenly heated without the contact of a sufficient quantity of heated air; and to this nuisance there are frequently superadded those of arsenical and sulphureous vapours, volatilized metals, and other matters, which spread widely around the works wherein they carry on the smelting of metals.

In the German mineral works, a long and large horizontal flue is interposed between the vent and the ascending flue of the chimney, in which the arsenical vapours are condensed, and collected for sale; but this is not always practicable, nor would it be always sufficient.

Mr. Jeffreys, of Bristol, has proposed a plan for avoiding this nuisance of arsenical fumes, and which may also be employed to condense and collect the smoke. His plan is to build two flues, either contiguous, or at any distance from one another, but connected at the top by a horizontal flue. The second flue is covered with a cistern, whose bottom is pierced with a number of small holes, like a common cullender; and this second flue has at the bottom an opening on the side to let out the water that runs down it.

Now, when the furnace is used, water is let on to the cistern at the top of the descending flue, which immediately runs in small streams through the holes in the bottom, which divide into drops as they fall, and carrying down air with them, produce a considerable draught through the flues, differing from the draught produced by bellows, or ordinary blowing machines, by being applied behind the fire, and drawing, instead of pushing the air through it.

This shower of water, as soon as it intermingles with the smoke and vapour of the fire, also immediately condenses and mixes with them, carrying them down, so that they run off with it through the opening at the bottom of the flue.

The efficacy of this mode has been completely established by experiment. The draught of air through the furnace was prodigiously increased; and although the ascending column of smoke was rendered as dense and black as it could well be made, yet not a particle of smut or smoke was observed to escape by the vent at the bottom of the water flue. A strong current of air, and a stream of black water issued forth, but nothing like smoke.

Though advantage may be derived in various ways from the application of this invention, and more especially where the expense of carrying it into effect bears but a small proportion to the advantages that will accrue; still it may be expected that many instances will be found in which the difficulty or expense of procuring the necessary supply of water, and possibly other causes, will operate as a total bar to its adoption. On the other hand, it is not improbable that time and reflection may discover remedies which, at the outset, may not occur: thus, when the furnace is used to heat a steam boiler, a part of the power may be expended in raising water for this purpose.

### *Conical Dome.*

In some chemical works the laboratory itself is the real chimney of the furnace, and is used to produce the necessary draught, as in glass-houses and potteries. In these manufactories, a large conical dome surrounds the furnace at some distance, so as to allow the workmen free access to it. This dome is carried to a considerable height, and surmounted at top by a short cylinder. The air then being admitted into the furnace from a vault under ground, passes through the fire, and out of the fire-room or chamber into the dome, by several openings above the level of the workmen's heads; and as no more air is admitted into the dome by the doors than is absolutely necessary for the respiration of the workmen, the fire receives nearly the full benefit of the velocity of draught produced by the height of the dome.

Chemists have sometimes endeavoured to imitate this construction in their small experimental laboratories, when they had only a wide recess with a single flue, like those formerly used in English kitchens, and still in farm-houses, for their chimney. To obtain a great degree of heat in their wind furnace, although its proper chimney rose only two or three feet high, they fitted a pipe of three or four inches diameter to

the ash-room of their furnace, and passed the other end through the wall of the laboratory; this end was sometimes widened into a kind of funnel.

As mere practical chemists have seldom much knowledge of hydrostatic and pneumatic theories, many have complained that they did not receive the benefit they expected from this air-pipe. This was because they neglected the necessary conditions for its proper action: which are, first, that the ash-room door be closely stopped so that no air may pass the fire but what comes through the pipe; secondly, that the windows and doors of the laboratory be accurately closed, and even paper pasted over the crevices to prevent any entrance of air through them, to create a false draught up the chimney; and lastly, that the door be not opened during the process, unless the operator be much distressed in his respiration, and then only for a moment. By these precautions being taken the laboratory becomes a part of the chimney, and the full effect of its height is produced.

### *Blast of Air.*

The introduction of a blast of air into furnaces, instead of depending upon their own draught, is used when it is not convenient to construct a chimney of sufficient height to produce the intended effect, or when it is desired to obtain this effect in a shorter space of time than would be required in air furnaces; as these last take a considerable time before they attain their full draught, by the mass of masonry, of which they consist, carrying off a considerable portion of the heat, until it becomes so well heated as to require no farther addition, except to supply that portion which passes through the walls themselves.

Two methods have been employed to produce this artificial blast. The oldest is probably the water blast, or that produced by the air, which is carried down by a shower of water made to fall a sufficient height. As this fall could not always be obtained where a blast was wanted, recourse was had to bellows of various construction, and blowing machines.

On both these methods the blast, as originally produced, is more or less unequal, and requires regulation. Three modes are used for this purpose: in the one the blast as it issues from the machines is introduced into a chamber of very great size, either constructed of iron plates, or masonry, or cut in the substance of a rock, by which means the unequal blast of the machines is equalized, and it issues out at the other end in a regular stream.

In the second method, the blast is thrown into a vessel with a moveable top, sliding up and down in it at pleasure, it being

kept horizontal by an iron standard or rod, rising from its centre and passing through a hole in a cross piece fixed above the vessel: this sliding moveable top is loaded with as much weight as is judged necessary. The blast then being sent into this regulator, as it is called, raises the moveable top, and the weight placed on it regulates the strength of the blast.

In a third method, the blast is first thrown into a large vessel of wood or iron plates, opened at bottom, closed at top, and fixed in a large cistern of water. Here the water, being driven out by the blast, rises in the cistern, and by its pressure regulates the blast to the furnace.

### *Provision to be made.*

Previous to *building furnaces*, it is necessary to provide the iron work necessary in their construction, that no delay may take place.

An iron door with its frame, for the lighting of the fire, and taking out the *scoria* of the coals, is requisite for most kinds of them; but, as such doors are commonly intended for the farther use of feeding the fire with fuel, they are made much larger than is necessary. If that method be not used, it is yet proper, always, to have them as long as the fire-place, or area made by the bars. They need not, however, for ordinary furnaces, be more than four inches high, where they are not designed to serve for feeding the fire. For, the lower they are, the less they will be capable of injuring the proper draught of air through the fuel, by making a false one; and the less liable also they will be, themselves, to warp and be out of order. They should be made of hammered iron, lined with a plate of cast-iron well riveted to the other. The usual form will very well serve, if the latch to keep them shut be made bigger than common, and carried across the whole door, to give it strength to resist the weight of the fuel, which otherwise, when the iron is softened by violent heat, forces the middle part outwards.

A proper cast-iron frame is necessary to be provided, for the hole through which the fire is to be fed with fuel, when that method of doing it is followed. The frame must be made of the size and form of the hole, which, in middling-sized furnaces, may be four inches wide and three high, or bigger where the furnace is large. The bottom plate should project six or eight inches beyond its joining with the side plates, and be four or six inches wider, in order to form a slab, on which the stopper, or stopping-coal, may be laid. This stopper is usually a brick, which does full as well as any other thing. The frame itself may be merely a slab of cast-iron, about a foot square, or even a tile of that dimension, and the top and sides formed of wrought-iron bars, bent into the proper form.

Plates and broad bars are also generally wanted, to be laid where brick-work is to be raised over the hollow parts of furnaces. Where larger plates are required, the cheapest and best way is to have them cast of the exact dimensions wanted. But, when a broad bar or two, laid together, will answer the end, the easiest way is to have them cut off of a proper length, from the bars of hammered iron, at the ironmongers. The right proportion of them may be easily computed, by estimating the proportion of the parts of the furnace they are to be subservient to, which should be always carefully done; and the workmen should be apprized, by written instructions and drawings, of the size and measure of every thing they are to erect or put together.

In chemical manufactories, the proprietors should contrive to continue their processes night and day, or if that is not practicable, they should stop all the openings in the furnace so close as to prevent the furnace from cooling during the night. Furnaces thus kept constantly hot, will last six or seven times as long as those will do which stand frequently idle. The contraction of the ma-

terials during the time of cooling, alternating with their expansion when they are again put into use, wear them out very rapidly.

When this continual use of the furnaces cannot be adopted, some chemists, in order to make them last longer, bind them with iron bars, either screwed together, or fastened by loops and wedges; others, taking advantage of the cheapness of cast-iron in England, enclose them in cases of that metal, cast for the purpose, with proper openings; the several parts of which case are screwed or pinned together.

For common furnaces, thin flat bars of tough iron, about eight inches longer than that part of the furnace where they are to be inserted, slit for four inches at each extremity, and the ends turned up, are built in each alternate course round the fire-room and chamber; by which means the expansion of the furnace is attempted to be checked, and its retraction secured.

The usual method of bricklayers building in pieces of small hoop-iron between the courses of brick is a ridiculous absurdity. Nor should a chemist allow them to plaster over his furnace, or surround their edges with cloth, or sheets of lead. If there be fear of the edges getting chipped by pails or other vessels, let them be surrounded with an iron hoop, or if this should be prejudicial to the materials which may be at times dragged over them, then the edges may be made of a wooden curb, fastened together with tree-nails.

## FURNACES FOR CHEMICAL OPERATIONS IN GENERAL.

### *The Stove-Holes.*

The stove-holes, as they are usually called, are the most useful of all furnaces; and, although this is so generally known that they are not only to be found in all druggist's laboratories, but also in all well-furnished kitchens, where they are used for the nicer operations of household economy, yet they have of late years been omitted to be described in any of our elementary treatises of chemistry, which have, instead thereof, descriptions of Cramer's athanor, or tower, furnace and other over curious contrivances, never used in English laboratories.

Stove-holes are generally constructed in pairs, it being frequently necessary to mix together two liquids at different temperatures, each of which, of course, requires a separate fire to prepare it.

Fig. 1, which is drawn on the scale of half an inch to a foot, represents the most approved construction: first, a space, *a*, *b*, *c*, on the floor, is marked out under a chimney, or hood, that may carry off the vapours. This space is to be thirty-seven inches and a half wide, and twenty-one inches from front to back. This space is to be surrounded by a wall of bricks laid on the flat sides, and with a similar wall in the middle of the open space. These walls are to be carried up to the height of two feet, by which means, two hollow prismatic ash-pits of twelve inches square will be left, with a partition four inches and a half in breadth between them, and having the outward boundary walls of the same thickness.

By the ash-pits being thus tall, a good draught of air will be made, if at the bottom in the front of each ash-pit a hole, *d*, five inches by four, be left to admit the air, the ingress of which is to be regulated either by an iron door, a slider, or by brick wedges, which, being pulled out more or less, will allow more or less air to pass.

On the top of each of these ash-pits is to be laid a grate, composed of iron bars, seven-eighths of an inch square, set on their edges an inch apart, and connected by two end bars, which lie in two tiles, or pins, forming sufficient ledges in the walls of the ash-pits. The walls are then to be raised twelve inches above the grate, leaving in the front of each fire-place a fire-room hole, *e*, four inches high and five wide, whose lower edge is about one inch above the grate, which holes are to be closed by iron doors.

The tops of the fire-places are entirely open, and the walls are continued all round of an even height, except that the outer side-wall, *f*, of each fire-place, is to be carried up only six inches from the grate, and the remainder left open; to which open place, loose pieces of brick are to be fitted, to close it when it is not wanted to be open.

It is most usual to have all the walls half a brick, or 4 inches .5 thick, as already described; but as these thick walls occasion a waste of fuel and time in heating such a mass of brick-work, Weigel recommends the walls to be only three inches thick at the farthest. In this case, the walls are built of bricks set on edge, and they must be held together with iron braces, fastened round the furnace with nuts and screws, and then plastered over about half an inch thick of Windsor clay, or enclosed in a cast iron case made for this purpose.

As distillation by the retort is a frequent operation in chemistry, one of these stove-holes is usually fitted for that purpose, by having a cast-iron pot, about six inches over, and as many deep, set sloping in the open space left in the outer wall, and supported in this position by an iron stand adapted for the purpose, and set on the grate. The space between the mouth of the pot and the walls of the furnace is then filled up with pieces of brick and clay. The fitting in of this cast-iron pot, which is intended to contain the glass retort and sand, does not prevent the furnace from being used in many other operations.

When it is intended to use a high degree of heat, the top of the retort must be covered with sand: and for this purpose, the mouth of the pot must be covered with two plates of sheet-iron, having notches cut in them to let the neck of the retort pass; and smaller notches above these, even with the upper part of the mouth of the pot, to form a circular hole through which sand may be poured to fill up the pot entirely. These iron plates are kept in their proper places by pins inserted in holes drilled in the edge of the pot, or of the iron-bands of the furnace. This filling up the sloping iron-pot with sand has, however, the inconvenience of preventing the bottom of the retort from being seen.

The other stove-hole will then serve for melting any thing in crucibles, or pipkins, and may have, as well as the other, its cavity contracted by loose bricks put into it. The short wall on the outer side is convenient when only a small fire is required; or when it is intended to distil in a coated glass or earthen retort, placed on a piece of brick in the middle of the fire; and if an iron plate is placed over either stove-hole to form a sand heat, a small hole may, by taking out one of the loose bricks, be left for a vent, if there be no other.

It may easily be conceived that boilers, shallow pans of copper, or even a small copper or tin plate still, may be placed over either of the holes, and, in short, that every operation may be performed with them, except such as require an excessive heat.

As charcoal or coke is usually burned in these stove-holes, they have in general no vents or flues, but if it is intended to burn raw pit coal in them, or any other smoking fuel, vents, *g*, must be made in the back wall about eight inches wide and three high, to carry off the smoke: these vents should be about three inches below the top of the furnace, and open into the flue of a chimney, which need not be of any great height.

In foreign laboratories, some of the stove-holes are made with the fire-room from once and a half to twice as deep as it is wide. These deep stove-holes, also, have a couple of iron bars placed across them from front to back, about midway from the grate to the upper edge; which bars are intended to support an earthen retort, an iron-pot for a sand-bath, or any other vessel. These are the furnaces which are called *reverberatory furnaces* by the French authors and their translators, and *distillatory furnaces* by the Germans. As the chemists in those countries universally use charcoal for their fuel, their stove-holes have no vent in the back wall opening into a flue; but in distillations by the naked fire, after stopping up the side opening with clay, the French cover them with a dome of baked earth, the upper part of which is drawn out into a short chimney a few inches in length; and the Germans are content with covering them with a flat slab of fire-stone or a large tile, leaving small openings at the corners for the sake of the draught.

## *The Furnace for the Sand-pot and Sand-bath.*

The furnace for the sand-pot and sand-bath is a very important and useful furnace; but in the usual way of building such furnaces, they are not only defective and faulty, in all the general points before mentioned, but in others also, respecting the proper proportion of this particular kind. This furnace is intended to serve for the sublimation of salts, and distillations of all kinds performed in retorts, as also evaporations from glass or wedgewood dishes. It heats at the same time, when advantageously constructed, a sand-pot and sand-bath. In the sand-pot any operation may be performed in one retort, where the degree of heat required is from that of boiling oil to the first degree of glowing heat, or what is called red-hot. In general, the retort is sunk in the sand, and even covered with it; but sometimes only as much sand is put in the pot as will keep the retort steady, and this is called a *capella vacua*.

In the sand-bath may be performed several distillations, where different degrees of heat are required, from that of boiling spirits of wine to that of boiling oil, as the bath may be made large enough to contain five retorts or other vessels of the same magnitude, which, by being placed nearer or more remote from the sand-pot, or fixed higher or lower in the sand, may suffer the several degrees of heat each shall require.

The first step towards making this furnace is to procure a proper sand-pot, and two large plates for forming the sand-bath. The size of the sand-pot must be determined by the magnitude of the retorts, or bodies, intended to be used in it. It must be so proportioned as to hold the retort, and to allow about two inches space for the sand to surround it on every side. The best form of sand-pots is that of a cylinder with a concave bottom, which ought to be made double the thickness of the sides. The common pots are generally made with thin bottoms, which subject them to be very soon worn out, if exposed to a strong heat

The plates for the bath should also be of cast-iron, and must be proportioned to the size and number of retorts, or other vessels, proposed to be worked. They must be long enough to allow at least two inches space betwixt every retort, and two inches and a half betwixt them and the sides of the bath, with the addition of two inches for its bearing on the sides of the hollow it is to cover: the same proportion must be observed for the breadth. They may be as thin as it can be well cast, but care must be taken not to break them in the moving or fixing, which may otherwise very easily happen.

A flat ring of iron, of about three inches breadth and of a proper magnitude to receive the edge of the pot into a proper groove or rabbit made in its own inner edge, should also be provided.

Two iron doors, with their proper frames and bars for the ash-hole and fire-place, and also an iron frame or slab and bars for the hole for feeding the fire, with other bars and plates for the hollow parts of the furnace, must likewise be prepared, according to the general directions above given.

When the iron work is thus prepared, the particular manner of constructing the furnace must be as follows:—

The dimensions of the furnace must be first settled by this method. It will also serve for obtaining those of any other kind of furnace designed to be built, where the object to be heated is of a constant or fixed nature.

The diameter of the sand-pot intended to be used being first taken, six inches must be added to it, for the cavity round the pot, and also the length of two bricks, to allow for the thickness of the sides of the furnace. These being put together, give the diameter of the whole furnace. To find the due height, the height of the pot must be first taken; to which must be added eight inches for the distance betwixt the pot and the surface of the fire when at the highest; six inches for the depth of the fire-place, and eight inches for the distance of the bars from the ground of the ash-hole; with the height of a brick for a course that must be carried over the edge of the pot, which being all put together, give the height of the whole furnace from the foundation.

A round or square cavity must then be made in the ground, on the place where the furnace is to be erected. This must be large enough to admit the laying the foundation of the furnace in it, and about eight inches deep, that the bars of the fire-place may lie on a level with the ground, the ash-hole being below it.

The reason for making this part of the furnace below the ground is to prevent the other parts from rising too high. With respect to the sand-pot, this is a great inconvenience to the operator when he has occasion to put a charged retort into the pot; for in doing this he greatly loses his command of it, if the pot be placed high. But still greater will the inconvenience be with regard to the sand-bath, which being of course considerably higher than the sand-pot, requires in this case that the operator should have something to stand upon, in order to manage the full retorts set into it;—an expedient always to be avoided.

The ground plan or foundation of the furnace must be laid in this hole, of dimensions suitable to the diameter, as computed by the rules above given, and carried up of solid brick-work, of a cylindrical or square form. But an area, *a*, must be left for the ash-hole, which must be proportioned by laying the bars fixed in their proper situation, by means of the cross-bearing bars in the ground, in the centre of the cylinder, and drawing two lines, begun at the farthest cross bar, and continued parallel to the two outermost bars, at the distance of a quarter of an inch from them, to the front of the cylinder. The space so described must be left hollow, and the ash-pit door set in the front. This part of the work may be done with common bricks and coal-ash mortar; but they must be laid solid, that the whole mass may not shrink when the mortar shall be subjected to a great heat. The cylinder of brick-work being thus raised about eight inches high, the bars of the fire-place must be laid over the innermost part of the vacuity left for the ash-hole; and the stoking-door, with its frame, *b*, must be also placed in front of the bars; but they will not, in this manner of construction, coincide with the interior surface or front wall of the furnace. The brick-work must then be again carried up six inches, in the same manner as before: only it must be made to take proper hold both of

Fig. 1.

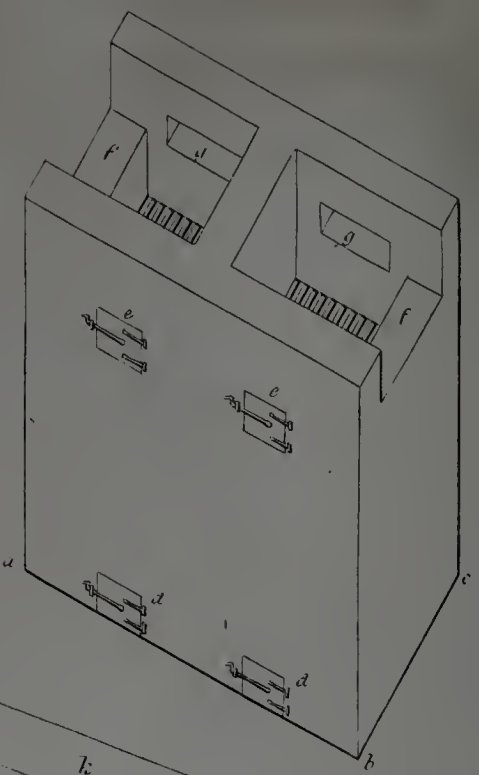
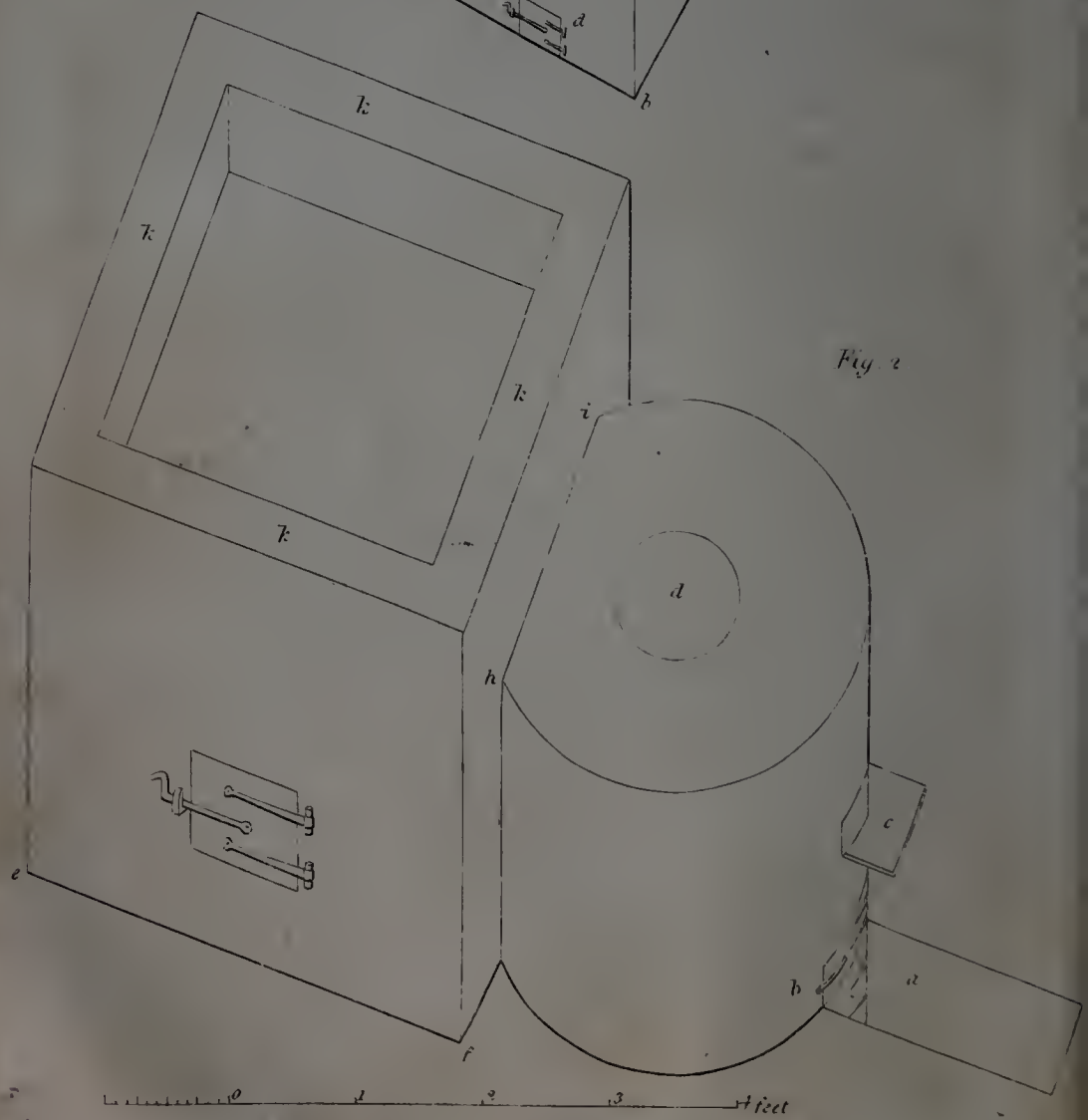



Fig. 2



the cross-bars of the fire-place and frame of the door. But the courses next the fire must be of Windsor brick, and laid with Windsor loam, or Stourbridge clay. If the heat be intended to be very violent, the joints next the fire should be pointed with the fire-lute hereafter mentioned.

When the fabric is raised to this height an iron plate of sufficient strength, or two broad bars, should be laid over the void part or opening, leading to the door and ash-hole, that the brick-work may be carried entirely round above. The cylinder must then be continued as before, only the cavity must then be made sloping from the upper part of the area designed for the fire-place, and enlarged gradually, so that in raising the furnace eight inches higher, the diameter of the cavity shall be six inches more than the diameter of the sand-pot. These six inches are to allow for the three inches distance betwixt the pot and the sides of the furnace, that will here begin to be parallel. The slab for forming the hole, *c*, for feeding the fire, as before described, should be fixed in the last course of bricks which make this slope. The most convenient situation for it is the front of the furnace, directly over the opening for the door and ash-hole.

From this height a cylinder must be carried up parallel to the sides of the sand-pot, at three inches distance, till within something less than the third of the top of the sand-pot, supposing the bottom to be on a level with the first of this cylinder. The hollow then must slope gradually inwards till it be no wider than just to suffer the sand-pot to be let down into it.

In the brick-work of this upper slope must be left a cavity for conveying the smoke and flame under the plate of the sand-bath. It must be in the centre of that part where the fabric of the sand-bath joins the furnace, and should be four inches and a half, or five inches in length, and about two inches in height.

The whole of this part of the furnace may be of common brick, but the mortar should be of Windsor loam. On the top of the brick-work raised to this state, must be laid the iron ring or rim before-mentioned, designed to hold the sand-pot.

It should be laid in with fire-lute, and well pointed with the same at the joint it makes with the bricks within the hollow of the furnace. A proper plate should also be laid over the cavity left for carrying the smoke and flame under the sand-bath.

When these parts of the furnace are so dried as to hold well together, the pot, *d*, should be let down into the ring, where it must hang by its own rim or turned edge, and another course of bricks then be raised in a continued line with the sides of the sand-pot: that part of them which touches the pot being laid in fire-lute, and the other parts in coal-ash mortar. In this course a slope must be made on the side opposite to the sand-bath or front, which ever shall appear most convenient, for the neck of the retorts to bend sufficiently downwards when placed in the pot. The whole of the furnace which relates to the sand-pot being so completed, the sand-bath must be thus added.

A ground plan or foundation, *e f*, must first be laid, which needs not, in this case, be sunk below the level of the flooring of the place; it must be proportioned according to the size of the plate intended to be used. The length must be that of the plate, with the addition of the breadth of two bricks; the breadth must be that of the plate, and the length of two bricks. It must be formed by building as it were four walls that mark out this proportion; the area within them is to be well paved with square tiles and left hollow. The walls may be built with common bricks and common mortar: only great care should be taken that the bricks may rest every where on each other, so that there may be no settling when the work shall be dry: and that a large iron door and frame be firmly fixed about the middle of the front wall. In adjusting the site of the area marked out for this foundation, about three inches length of the side of the furnace round the sand-pot must be taken into the end of the area next it. This projection of the one part of the furnace into the other, *h i*, is necessary, in order to bring the end of the plate close to the flue; that is, to convey the flame and smoke into the cavity under it, without being obliged to lengthen the passage, which otherwise must be the case if the whole square

of the brick-work of the sand-bath was built in a distinct area, on the outside the round building for the sand-pot.

The four walls, as before directed, must be carried up till they rise to the level of the lower part of the flue for conveying the smoke and flame.

One of the iron plates should then be made over this square body; it must be laid in coal-ash mortar on the under side, and the joints on the upper side pointed with Windsor loam.

On this iron plate another empty area must be formed by laying rows of bricks at such distance that the upper plate may rest on them one inch on each side. They must be laid endways to each other; and, for the sides next the plate, Windsor loam should be used; but for the other part coal-ash mortar. The upper plate, *e*, must be then laid on them, and set with fire-lute.

The openings at the two ends into the cavity under the plate must be likewise closed up by bricks laid breadthways; the same caution being used as before for the inside with respect to the kind of mortar. But the opening of the flue for conveying the smoke and flame under the plate must be preserved, and likewise another opening at the other end for the passage of the smoke into the chimney; over which opening a plate, or broad bars, must be laid to support the brick-work of the side over it.

A course of bricks, *k*, laid breadthways, must then be raised close to the edge of the plate entirely round it; the joints where they meet the plate being made good with fire-lute, but the rest with coal-ash mortar. Over this course as many others may be laid, but with coal-ash mortar only, as will raise the sides of the bath to a due height; and this must be regulated by the size of the retorts to be used in it.

The chimney for this furnace should be at least twelve or fourteen feet high, and have a cavity of about six inches square.

If this kind of furnace be completed according to the directions here given, and gradually dried, it will continue in order, if carefully used, for a long time. And when the sand-pot, which will be the first part of it that will fail, shall become unfit for farther service, the course of bricks above it being removed, it may be taken out of the ring, and the fire-room and other parts of the cavity being repaired and well pointed, a new one may be put in its place, and the course of bricks above it restored. This may sometimes be repeated a third time before there be occasion to take down any other part of the furnace.

For general purposes, the sand-pot is usually twelve inches over on the inside and about nine inches deep, the sand-plates about three feet by two feet, and the door into the oven twelve inches wide, and nine inches high.

Dr. Henry and others have described furnaces for sand-plates only, to be used for the performance of digestions and slow evaporations; but although distillation by a considerable heat may not be required, it is preferable to construct a furnace of this kind with a sand-pot; if no other use is made of it a flat bottom mattrass, or a Boyle's hell, may be placed in it, with some quicksilver therein, for preparing the red oxide as a secondary operation; which will also serve as a thermometer to regulate the heat of the other part; and thus a valuable article will be prepared with no other expense than the original cost

of the metal. This preparation seems the best use that the sand-pot can be put to in this case, because it allows of frequent interruptions without any inconvenience.

That part of this furnace which regards the sand-pot only, is the model on which pot-furnaces of various sorts may be constructed without a sand-plate attached; such as those for heating cast iron or copper boilers, for different purposes; the leaden and pewter boilers of the colour makers, and, in general, all cylindrical or hemispherical vessels; in which last class may be reckoned the coated glass mattrasses in which camphire is sublimed; except that in many of these variety of uses the course of bricks placed over the rim of the sand-pot is omitted; and, of course, the vessel, merely hanging in the ring by a flange, or trunnions, may be taken out and put in again at pleasure.

When the vessel is very large, as in the large coppers for brewing and for evaporating saline liquids, the weight of the fluid contained in it requires that it should be supported at bottom. For this purpose, walls are generally used, and a passage is left between them for smoke and burned air; but the more ancient plan of using pillars only is preferable. The pillars may be about nine inches square, and being disposed chequer ways, as far as is possible, they break the current of air and distribute it equally under all the surface of the boiler.

This construction has the inconvenience of the indraught of air rushing, every time the feeding door is opened, across the top of the fire, cooling the furnace and vessels, and sometimes causing them to crack. When it is desired to avoid this inconvenience, Mr. Losh's plan must be adopted.

Fig. 3, represents a vertical section of a pot, boiler, or kettle, set upon that gentleman's principle, and drawn on a scale of one quarter of an inch to a foot.

*a*, shows the pot or boiler; *b*, the grates or bars on which the fuel is burned and placed rather behind the centre of the boiler; *c*, a dead plate, or the partition which separates the ash-hole, *d*, from the fire-room; *e*, the feeding and stoking-door frame; *f*, the pillars on which the boiler rests, with a bearing of six inches; *g*, the space surrounding the edges of the boiler, into which the heated air ascends from the fire-room through the openings between the pillars; *h*, the chimney.

On the above plan all manner of small boilers and pans may be set which require the heat to be applied to the sides as well as the bottom; also all kinds of stills, sugar-pans, or boilers, soap-pans, and boilers for evaporating alkaline and other saline solutions, and for precipitating the salts they contain, &c., it being understood that the dimensions of the plan must be adapted to the boiler or pan to be placed upon it. Steam-engine boilers, and other large boilers, may also be set on this plan; but the application of two fire-rooms has the advantage of diffusing the heated gases more equally over the surface to be

heated, and the separation wall is of great use in supporting the bottoms of the boilers. By dividing the fire-room into three, four, or more spaces, separated from each other by walls, and each space containing a fire-room, the advantages of a still more equable diffusion of the heated air, and of a more effectual support to the boiler, would be obtained.

Fig. 4, represents a vertical section of a steam-boiler and furnace, with two fire-rooms; drawn on a scale of one-eighth of an inch to a foot.

Fig. 5, represents a horizontal section of the same; *a*, a wall which extends from the bottom of the ash-hole to the bottom of the boiler, and to the top of the flues, or space for containing the heated air, round the sides of the boiler. This wall cuts off all communication between the two furnaces and fire-rooms, or spaces for containing the heated air, and gives support to the bottom and sides of the boiler; *b*, shows the grates or bars on which the fuel is burnt; *c*, a dead plate which separates the ash-hole and fire-room, and prevents the ascent of the atmospheric air from the former to the latter; *d*, the ash-room door; *e*, the fire-room door; *f*, pillars on which the boiler rests, with a bearance of nine inches, more or less according to the size of the boiler, within the extreme periphery of the bottom; *g*, the boiler; *h*, the spaces round the sides of the boiler, into which the heated air ascends from the fire-room, through the openings between the pillars; *i*, spaces through which the burned air, after acting on the boiler, may be conveyed through flues, *k*, to one chimney, *l*, placed in any convenient situation, as shown in the plan, Fig. 5. In these flues, dampers may be introduced, by which the penetration of the air through the two furnaces may be effectually equalized, and, by inserting another damper in the chimney, both furnaces may be completely regulated.

As instances of the steady, rapid, and intense action of furnaces on this construction, a round boiler of thirteen feet diameter, without any flue through it, was not only brought to boil, but furnished steam of sufficient power to work a machine of twenty-horse power, put up by Messrs. Boulton and Watt, in eight minutes from the time it was filled sufficiently high with water, the fire being put in when the bottom was covered; and which engine was at work within the space of seventeen minutes from the time of its being filled with water.

A similar boiler, placed on the usual construction, required an hour and a quarter to raise the steam to the same degree of elasticity, as the boiler of this construction produced within eight minutes after it was filled above the flues, the fire being put in when the bottom was covered; and as it was a competition of skill, every possible exertion was used on both sides.

This plan has been applied to the boiler of an engine for drawing coals, at Killingworth colliery, in Northumberland, which, on the usual plan, was inadequate to raise steam to do the work required; namely, to draw forty score of twenty peck corfs of coals, in fourteen hours, from a pit 120 fathoms deep, although the engine, built by Messrs. Fenton, Murray, and Co., was well constructed, and kept in perfect order. The boiler is a round one, of thirteen feet diameter, without a flue

Fig 3

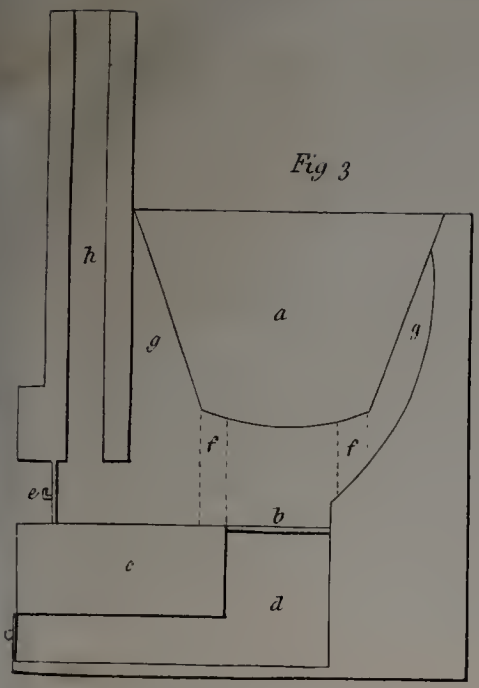



Fig 5

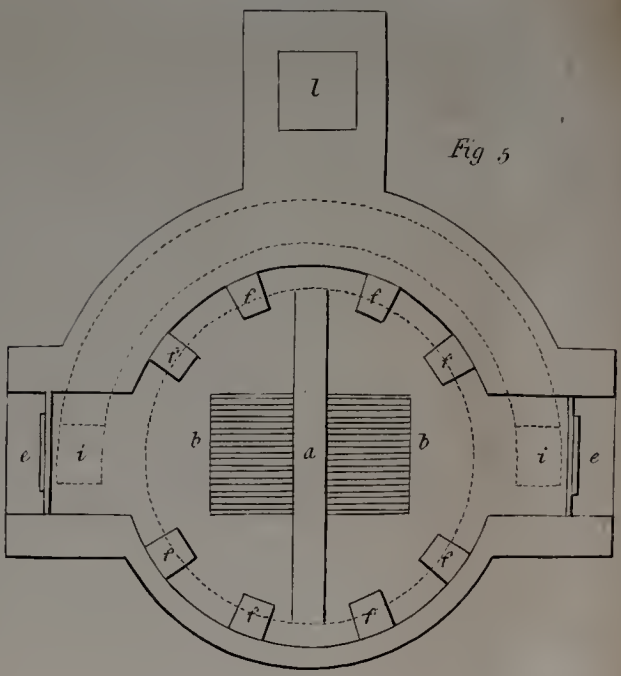



Fig. 4.

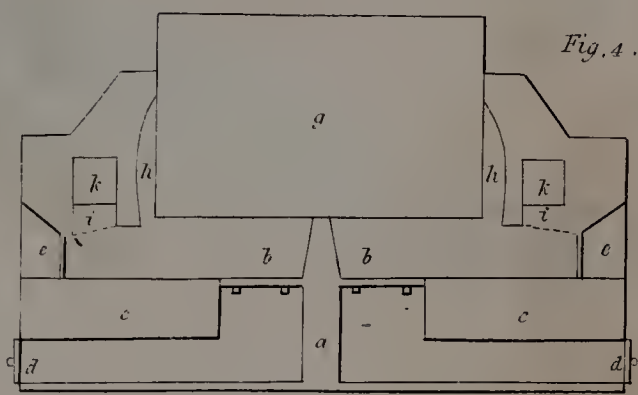
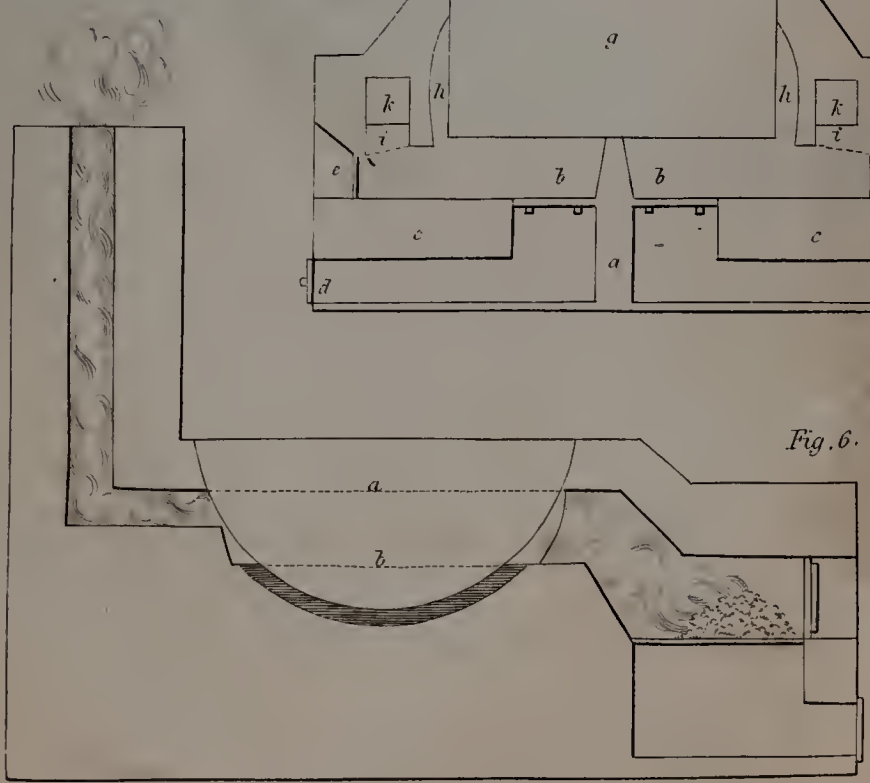
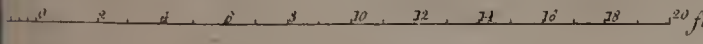



Fig. 6.





through it, and the cylinder of the engine thirty inches diameter. Since Mr. Losh's plan has been adopted, the engine performs the work with perfect ease, although nothing but the smallest refuse coal is employed, and that only in the proportion of one-half of what was used before the improvement, without producing the desired effect. The engine will now work at its full power for nearly an hour after a fresh supply of fuel; whereas, on the former plan it was requisite to give a fresh supply every ten minutes, or oftener. And although the effect of the heated air is so powerful, yet the fire itself is so moderate, and the combustion of fuel so gradual and perfect, that no scars are formed; and in consequence it is only found necessary to clean the grates once in two days, although the coals are of that quality which have a great tendency to vitrify at a high degree of heat.

The only instructions necessary relative to firing, or adding fresh supplies of fuel to boilers on this plan, are, to throw in much less at once than is usually done, to keep the bars well covered, but the fuel much thinner upon them, and the fires much brighter than in common furnaces; to wait after adding coals to one furnace, till it has become bright, before a fresh supply is given to the other; so that when one fire is at its highest degree of heat, the other is at its lowest, and thus the boiler may be kept continually at nearly an equal temperature;—the advantages are evident.

### *Salt Boilers.*

It is a fact well known to those who are interested in chemical works, that boilers of cast iron, with their bottom fully exposed to the fire, cannot be employed with safety either in lixiviating ponderous substances, or in concentrating the solution of any salt which crystallizes at the surface of the liquid by evaporation; because in the former case the mass of the materials resting on the bottom of the vessel; and in the latter, the crystallized salt which falls down, is apt to fix on the bottom of the boiler, and ultimately to rend it.

Although boilers made of malleable iron are not subject to the same inconvenience from these causes, yet in a number of cases they cannot be employed with safety. In the solution of a salt, for instance, which contains the smallest predominance of any of the mineral acids, these acting on the joints and rivets, in a short time corrode, and render them unserviceable, which frequently causes not only loss but disappointment.

The boilers which are found most advantageous to use for the evaporation of dense liquids, where the salt crystallizes at the surface by evaporation, such as muriate of soda or sul-

phate of potash, are those commonly called *sugar-pans*, which contain from one hundred to three hundred gallons English wine measure. The form at bottom is nearly a semicircle. They are used in the West India islands for evaporating the solution of sugar, and from long experience are found well adapted for this purpose.

Fig. 6, is a representation of one of these vessels capable of containing three hundred gallons: the depth is two feet seven inches, and the width at top six feet two inches. The bottom of the vessel is set in solid brick-work, bedded with fire-clay, as represented in the drawing, to the depth of the dotted line, *b*, The space between *a* and *b* is the vacancy where the flue encircles the boiler, to heat it, which communicates with the vent, *c*, for the escape of the smoke. The boiler is kept constantly full of the solution, which is evaporating, above the dotted line, *a*, so as it may not be in danger, when heated, from the cold solution which it may be necessary to add to it.

After a saline solution is so far concentrated that the salt begins to form on the surface, from the peculiar manner in which the boiler is built up, it is evident that the boil must proceed from the circumference to the centre; and the salt, from its density, falling down as it is formed, is deposited under the dotted line, *b*, in a loose state, and when a sufficient quantity is thrown down, it is drawn out by the workmen with iron ladles, formed on purpose.

From experience, we know that salts, with a proportion of an earthy basis, such as sulphate of lime, when evaporated in boilers built up in the common mode, with the fire-place directly under the bottom, are deposited, and incrust the bottom so much as to be with difficulty detached from it; and when these deposites increase to any degree of thickness, from the vibration of the boiler by the increased temperature, it is frequently rent when least expected.

On the contrary, when boilers were built up in the manner described, not a single accident has occurred during two years; and boilers have been built up which were formerly so much rent at the bottom as to be no longer useful; but when placed on a bed of fire-clay, supported by brick-work to the depth of the extent of the rent, they were rendered completely serviceable.

As to the expense of fuel, until the vessel is brought to the boiling temperature, a strong heat is necessary; but for the continuance of the boil and evaporation, a fire of coal-dross is sufficient, when proper attention is given by the man who has the charge of these boilers.

The Dutch dyers use a similar manner of setting the boilers in which they dye blue, as a very considerable sediment settles at the bottom of them, which, in the common way of having the boiler over the fire, would be liable to become burnt. They therefore make the boiler in the conical shape of a sugar loaf mould, and sink the narrow bottom a little below the ground, so that the heat of the fire only passes round the middle of the boiler.

This manner of setting might also be employed in stills, when a considerable sediment is liable to be deposited; but in

all cases it will be necessary that the boiler should not be cylindrical, or with upright sides; but rather being hemispherical or conical, that the sides of the circular flue being by this figure made sloping, the heat of the air passing through it may be better communicated in this way.

The principle adopted in this manner of setting the pans, namely, of passing the heated air of the fire round the middle of the pan, without touching the bottom of it, is contrary to that adopted by the soap manufacturers, who apply the fire only to the bottom of their boilers.

This may have arisen anciently from the difficulty they might have found of obtaining iron pots of sufficient size for their use, whence they formerly, in this country, and still on the continent, use boilers which have only the bottom made of iron, the sides being either formed of wooden staves, or of masonry.

### *The Copper Still.*

A copper still is set up in a furnace similar to that for the sand-pot already described; except that the ash-room is not sunk in the ground, and is even made tall, in order to raise the still, and allow more height for the condensing apparatus.

A number of various forms have been invented for the stills used to distil ardent spirits, and will be described hereafter. For general purposes, a plain cylinder, about one-fourth wider than it is high, will be found the best form. Not more than one-fourth of its height should be exposed to the action of the fire; nevertheless, if it have a furnace to itself, it will be proper to build up the brick-work to the very mouth, in order to confine the heat, render less fuel necessary, and prevent the condensation of the vapour on the sides, where it would run down again into the liquid not yet raised. If, from the furnace being also used for other purposes, the still is only occasionally hung therein, or any other cause, the uncovered part of the body and neck ought to be wrapped up, when in use, with thick blanketing.

The neck of the still should be at least a foot long, and towards the side there should be soldered a short pipe about an inch long, and half as wide. This pipe is usually closed by a screw top, or a cork having a bladder tied over it: the pipe in this case has a ring soldered round it to hold the string. By this hole the still may be charged without taking off the head, or emptied by a syphon or crane; the larger stills have usually a pipe and cork at the lower part for emptying them.

The third part of the copper still is the head. The moor's head, for general purposes, is far preferable to the swan's-neck head, generally used by the distillers and rectifiers of ardent spirits, as in this last form, whatever is condensed in the head

returns again into the body of the still. This is indeed, in some measure, necessary on account of the shortness of neck given to the bodies of their stills.

The neck of the moor's head is generally about six or eight inches long, the head itself is cylindrical, and closed at top with a hemispherical arch. It is rather wider than the neck, and overhangs it so as to form round the neck a channel or groove, which carries the distilled liquor, as soon as it is condensed, into the nose or pipe, which carries it into the receiver.

As the distillations in which the copper still is employed are generally carried on as quick as possible, means are used to hasten the condensation of the vapours. The distillers and rectifiers use for their condensing apparatus, a worm or coil of copper or pewter pipe, placed in the lower half of a large tub of water; but although this method is very effectual, the worm is very expensive, and totally unfit for general purposes, as its winding shape does not allow it to be cleaned out from the fatty matters which sometimes come over in distillation.

The most simple method, and which is fully sufficient for the purpose, is a straight pewter or tin plate pipe, passed through a butt of water, or, which is still better, through two smaller casks placed close together. The use of a plain straight pipe does not indeed allow the operation to be driven on so quick as when a worm of a very large size is used, but in every other respect it is superior.

This pipe should be from four to eight feet long, and set on a gentle slope, yet so as to allow the distilled liquor to run off as fast as it is condensed.

The butts or casks are usually set upright, and the pipe passes through them transversely; but some persons place the casks on their sides, and pass the pipe through holes made in their heads.

Mr. Acton has shown the utility of employing two coolers to the condensing pipe of a still.

A worm-tub of thirty-six gallons being connected with a nine-gallon still in action, the water soon became so hot as to require changing. But when a horizontal pewter pipe, rather more than three feet long, two inches in diameter next the still head, and three quarters of an inch in diameter next the worm, was used as an adopter, and passed through a trough of water three feet long, twelve inches deep, and fifteen inches wide, the distillation could be carried on for any length of time without raising the water in the worm-tub a single degree, as the heat became accumulated in the water in the trough, and when elevated to 140 or 150° passed off by evaporation.

Small stills have their heads surrounded with a kind of circular cistern called the refrigeratory. This cistern is soldered round the neck of the head, is a few inches wider than it, and rises a few inches higher than the top. The refrigeratory, when filled with cold water, acts like the first cask just men-

tioned, and the water, absorbing the heat brought over by the steam or vapour, grows hot. When it arrives at a certain temperature, part should be drawn by the cock in the side of the cistern, and some cold water added. For the sake of making use of the hot water notable housewives wash the same day they distil.

When tubs or casks of water are not at hand, or out of order, and the still has no refrigeratory, the adopter or condensing pipe may be merely covered with some coarse cloth tied loosely round it and wetted. As the hot vapour passes through the pipe and is condensed on its sides, the pipe and wet cloth are heated, and the latter begins to steam. To supply it continually with water, a small cask or jar, with a hole in its bottom, is supported or slung in such a position over the pipe, that on the cock of the cask being slightly turned, or the cork being loosened, the water may drip or even run in a very small stream, on the upper end of the pipe, and thus keep it continually moist.

The apparatus invented by the elder Weigel, a chemist and druggist of Stockholm, is more elegant, and has been adopted by a number of chemists, in preference to the cumbersome worm and its tub. In Mr. Weigel's method the condensing pipe is straight, and cased, for the greater part of its length, in another pipe about an inch and a half wider, leaving about eight inches at each end uncased.

A leaden pipe, bringing water from a cistern placed on a higher level than the head of the still, is soldered into the lower end of the casing. This water pipe is furnished with a cock in some convenient part of it, to stop the passage of the water, or assist in the regulation of the current, at pleasure. Another cock is soldered to the casing pipe, at its upper end next the still head, by which the water that passes through the casing may run off, in a greater or less stream, according as the cock is turned.

Now when the distillation is begun, and this cooling apparatus is to be brought into action, the two cocks are opened, according to the judgment of the operator, and the cold water from the cistern entering the casing pipe at its lower end, rises up along it, keeping the internal condensing pipe cool, and passes off through the cock at the upper end, either into pails, or is permitted to run to waste on the floor.

It would be a useless waste of water, which in many situations is very valuable, to allow more to run through the casing pipe than is necessary to condense the vapour.

As this requires a cistern of water on a proper level, which is not always at command, Mr. Danforth has proposed another method, in which the vessel containing the cooling liquid acts

as a syphon. The adopter or condensing pipe, with its casing, being supported at a proper height, on a moveable frame of wood work, a short pipe with a cock is soldered to the lower end of the casing, another short pipe to the upper part of the upper end of the casing, and a longer pipe with a cock to the lower part of the same upper end of the casing; this last pipe must be of such length that its lower end may be below the level of the lower end of the short pipe attached to the lower extremity of the casing.

Now to use this moveable condensing apparatus, a vessel of water being placed under the pipe attached to the lower end of the casing, and the cocks of both the pipes closed, water is to be poured into the casing by the short pipe at its upper part, until it is completely filled, when this pipe is closed with a cork. The cocks being then opened, the casing with its two pipes will act as a syphon or crane, and the water in the vessel will rise through the casing and pass off through the longer pipe, either into an empty pail placed there, or run to waste on the floor. The current is to be regulated by opening the cock of the longer pipe more or less.

The proper receiver to be generally used with these adopters is a matrass, having an *s* pipe in the middle of its height; so that if any oil come over with the distilled liquor it may be retained in the receiver, while the aqueous fluid is allowed to pass away by the pipe into bottles placed to receive it. The oil, if lighter than water, will float upon it; and, if heavier, sink to the bottom of the receiver.

Fig. 7, is the geometric representation of a still with a moor's head fitted with a syphon cooler, and close Italian receiver, drawn on a scale of half an inch to a foot. *A*, is the ash-room door; *b*, the place of the grate; *c*, the stoking-door; *d*, the feeding-hole for the fire, with its slab; *e*, the vent at the back of the furnace; *f*, the body of the still, which being thirty inches wide and twenty inches high, will hold, when half full, twenty-seven gallons; and when three quarters filled, forty-one gallons: *g*, a short pipe by which the still may be filled, or the liquor in it drawn off by a crane, without taking off the head; *h*, the neck of the head; *i*, the moor's head, with its nose; *k*, the adopter to lengthen the nose, which, for the sake of room, is represented only half the proper length; *l*, the cooling pipe, through which the water runs up, surrounding the adopter, and cools the vapour in it; *m*, the shorter pipe of the syphon, immersed in a broad shallow tub of water; *n*, the longer pipe of the syphon; *o*, the cock to the shorter pipe, placed at the very extremity; *p*, the cock of the longer pipe, which may be placed any where below the level of *o*; *q*, the close Italian receiver, retaining the essential oils, when the still is used for distilling those articles, and allowing the water to pass off by the spout, *r*.

Should a person prefer the use of a tub with the adopter sunk in the water, the following is the best construction for general purposes, as the straight adopter is the only one that can be cleaned.

Fig. 8, represents this tub, which is generally made of copper, or zinc plates soldered together. The adopter itself is made of three pipes, *ab*, *cd*, *ef*, each

Fig. 7.

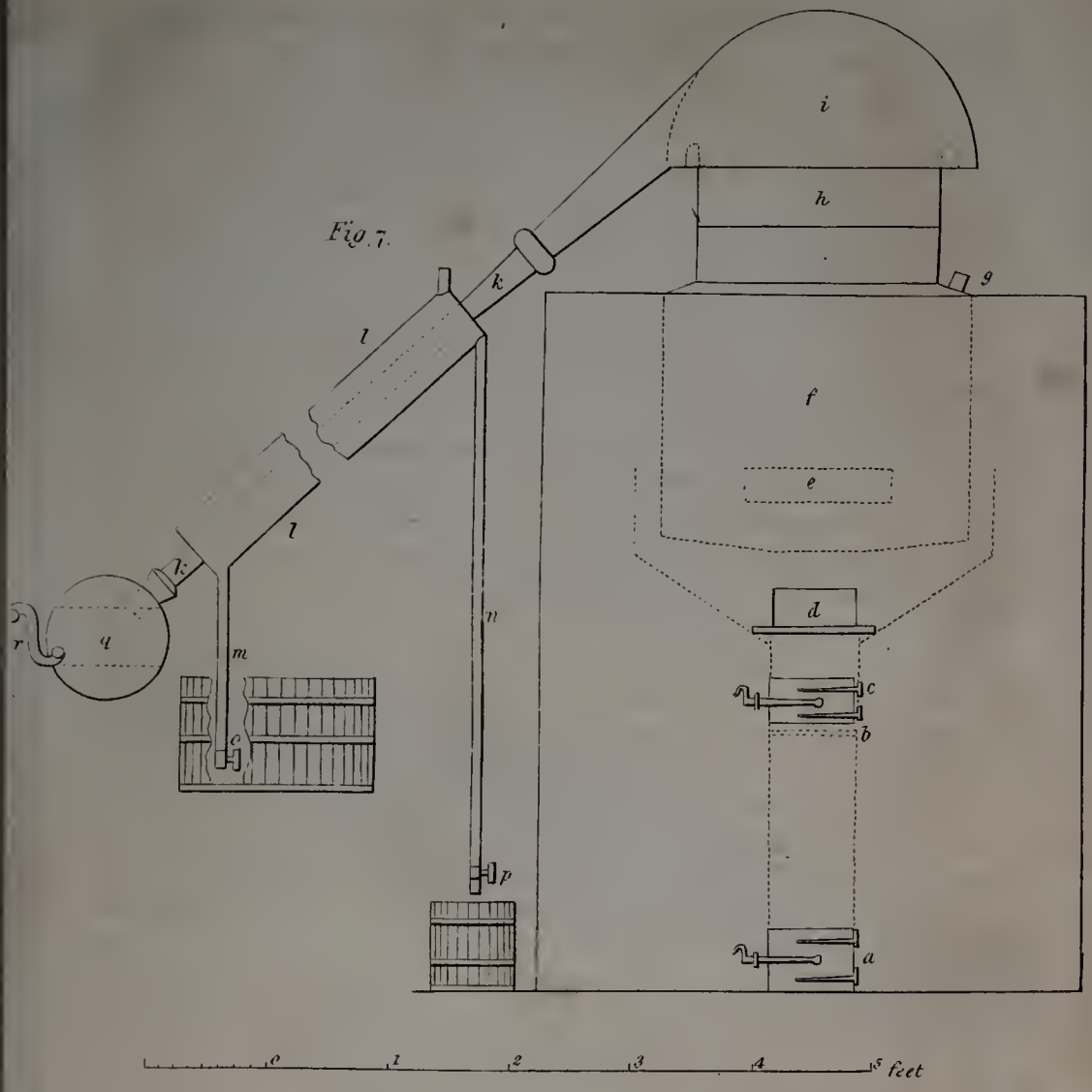
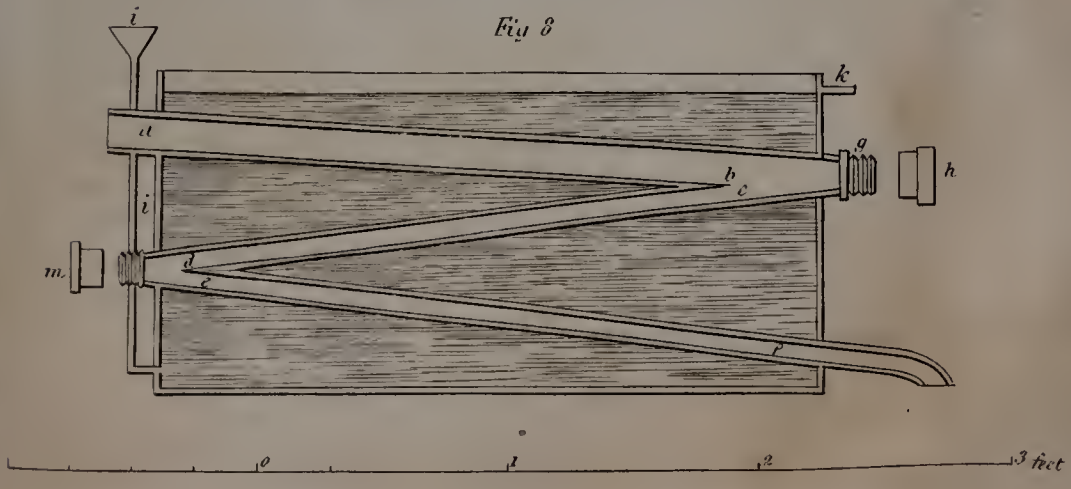



Fig 8



about a yard long, cut off sloping at each end, and soldered together, so as to form one continuous pipe. The ends of the pipes, which are also soldered to the tub, have a hollow ring, with an external male screw, *g*, *i*, soldered also to them, and on each of these is screwed a solid cap, *h*, *m*, having a leather ring placed between them, to secure the joint.

The tub containing these three pipes, or more, if it be thought necessary, need not be deeper, from front to back, than about three times the breadth of the widest pipe, as the water can be continually changed, when it grows warm by a gutter being conducted from the cock of the laboratory cistern to the funnel, *i*; and the warmed water will pass off by the spout, *k*. A cock soldered at the lower part of this tub is necessary to empty it occasionally.

The caps, *h* and *m*, being unscrewed, the pipes are easily cleaned by means of an iron rod, wrapped round with some tow.

## *The Water-Bath, or Balneum Maris.*

A vessel of hot water is often used as a medium for the communication of heat: and is then called a water-bath.

When a water-bath is used for evaporation only, then the boiler need not be deeper than two-thirds of its width; and the water-bath may be a hemispherical vessel, of rather less diameter than the boiler, to allow room for a short pipe, by which water is poured into the boiler, and another longer pipe, by which the steam is allowed to escape, and is directed into the draught of a hood or chimney, or into the ash-hole of the furnace. The furnace for heating the boiler is precisely similar to that for the still.

For distilling by the water-bath, a still of the ordinary form is surrounded by a boiler about four inches wider and deeper than the body of the still, with the same pipes as in the former case.

Some use a long narrow cylinder, which they insert, when wanted, in the mouth of the common still, but it is far better to have a peculiar still for this purpose.

For evaporation of liquids, another mode of heating them has been adopted in a few instances; as for boiling syrup, by the circulation of heated oil, forced by a pump through pipes immersed in the vessel containing the syrup. And the circulation of heated water has been used for hatching eggs on the large scale of a manufactory, and to heat green-houses.

## *The Steam-Bath, or Balneum Vaporis.*

The use of a steam-bath, or balneum vaporis, of the old chemists is, at present, in great favour with many chemical artists, in preparing articles on the large scale; but the apparatus necessary for the vapour-bath being rather complex, and the water-bath affording the same facility of tempering the heat, and restraining it within a certain temperature, it is seldom employed in laboratories for general purposes.

The original use of the steam-bath, as we learn from Gesner's Evonymus, was to serve as an elegant substitute for the heat of a dunghill, still used by gardeners. The steam was

conveyed by a pipe into a square wooden chest, filled with chaff, or cut straw, in which the vessels containing the materials were placed; the part of the steam-pipe that traversed the chest from end to end, was pierced with numerous holes, through which the steam made its way, and condensing on the chaff, heated it gently. The condensed water was allowed to run off at one corner of the chest.

Lemeri's vapour-bath was a flat-bottomed copper still, which fitted into the mouth of a boiler, with three pipes round it to allow the passage of the steam into the atmosphere.

At present chemists and housewives have, for common purposes, returned to the old form of the steam, or vapour bath. The water is boiled in a copper, or even tin-ware, kettle, set in a furnace. This kettle has a double cover that fits close, and on one side of it is a pipe, directed upwards. A square chest of thin plate iron, japanned, or even tin-ware, is placed in a convenient situation near the boiler, and with its bottom rather above the level of the mouth of the kettle. A pipe of the proper length forms the communication between this steam-chest and the kettle; this pipe enters into the pipe of the kettle, and is made to fit very close. The bottom of the steam-chest is set so as to slant a little, that the condensed steam may run down these pipes into the kettle again. The top of the steam-chest is pierced with several holes of different sizes, into which are fitted tin-ware vessels for the different operations intended to be performed. A pipe at the farther end of the steam-chest allows a passage to the surplus steam that is produced, and directs it either into the draught of the chimney, or of the furnace itself.

Fig. 9, represents a small laboratory steam-boiler, for steam of a moderate force, with its several appendages; *a*, is the ash-pit, with its door; *b*, the fire-room; *c*, the feeding-hole, with its slab, to be stopped with small coal; *d*, the stoking-hole of the fire-place; *e*, the lower gauge-pipe and cock, to know whether there is a deficiency of water, as in that case, steam will issue when the cock is opened; but if there is sufficient water it will come out of the cock: *f*, the upper gauge-pipe and cock, to ascertain whether there be too much water in the boiler, as in that case, water will issue through the cock when opened; but if there is not a surplus of water, steam will pass through the cock; *h*, the feeding-pipe, connected with the cistern of water; *i*, the cock which cuts off the communication between the cistern and the steam-boiler; *k*, a safety-pipe, bent at the top, so that if at any time the water should be forced up, it may be thrown into the cistern. The height of the upper part of the bend of this pipe above the level of the water in the cistern, determines the utmost strength of the pressure of the steam; *l*, the steam-pipe, by which the steam is conveyed where it is to be applied: this pipe is to be shut by a steam-cock, which ought to be so constructed that it cannot be at any time entirely shut, but that there may always remain a small passage for the steam.

This is all the apparatus necessary for the occasional application of steam to chemical works, when the temperature that is to be produced by the difference of the level between the up-

per surface of the water in the laboratory-cistern and that in the boiler is sufficient for the purpose. But when what is called high pressure steam is required, a more complicated apparatus is necessary, and the boiler must have an engine attached to it, as in that case the water cannot be introduced by a common feed-pipe by its own pressure, but must be forced into the boiler by a forcing pump, and is therefore more the object of engineers than chemists.

The steam-boiler, with all its hollow appendages, ought to be made very strong, so as to resist the internal pressure made against its sides by the expansive force of the steam contained within it, and also the external pressure of the atmosphere in case a vacuum should be formed within it by a sudden condensation of the steam.

For a laboratory steam-boiler, the upright cylindrical form is as good as any; but for engines, or heating rooms, a wagon-formed boiler is perhaps the most usual. It is generally made of iron, rather wide and shallow than the contrary, and the whole of the lower part, as high as the water reaches, is exposed to the fire. The greatest effect in producing steam is obtained when the horizontal area is about twenty-one square feet. The water in it is to be kept so as to half fill it; and for that purpose the gauge-cocks must be frequently opened, to see that the lower cock lets out water, and the upper cock steam. If both let out water, it is too full, and the upper gauge-cock must be left open till the water no longer runs out. If both gauge-cocks emit steam, the boiler wants replenishing with water, which in these small boilers, is effected by turning the cock of the feed-pipe, and leaving open the upper gague-cock to show when the necessary quantity has entered. In the large boilers of steam engines and the like, mechanical contrivances are adopted to cause the cock of the feeding-pipe, or a valve at its exit from the cistern, to open whenever it is necessary, by means of a float on the water balanced by a counter weight as hereafter described in treating of heating rooms. An attentive chemical operator will soon acquire a knowledge of the power of his furnace, and give a shrewd guess at the intervals which may be allowed between the feedings.

The safety-pipe should enter as deep into the boiler as that its extremity may be a little below the level of the lower gauge-pipe, or at the utmost half way into the water when the boiler is properly filled. Hence, should the operator omit to replenish his boiler with water, then as soon as the level of the water falls below the lower extremity of the feeding-pipe, the steam will rush up it, and appear at the upper end of the safety-pipe. This pipe may also be formed into the shape of a boatswain's-whistle, or organ-pipe, and then the steam passing

through it will give very audible notice of its being time to replenish the boiler with water.

In steam apparatus of this kind, the difference of level between the surface of the water in the safety-pipe and the surface of the water in the boiler itself, governs the temperature at which the steam is supplied to the pipes and vessels subject to its action, as also the pressure which it exercises against the sides of the boiler and pipes, which is usually quoted in avoirdupois pounds and decimals of pressure against every square inch of surface, but sometimes, especially in high pressure steam, by atmospheres, of 14 pounds ·75 each. The excess of this pressure, above that of which the atmosphere exercises against the outward surface of the boiler, &c., the latter being, when the barometer stands at thirty inches, 14 pounds ·75 on every square inch of surface, is the explosive power, which is quoted in the same manner as the pressure.

Every two feet and a-half in the difference of the level of the water in the safety-pipe and boiler, will cause the steam to exert a pressure of one pound above the ordinary pressure of the atmosphere on every square inch; and the connexion between the pressure and the temperature of the steam is seen in the following table:—

| Pressure on each square inch above the ordinary atmospheric pressure, estimated in avoirdupois pounds. | Temperature of the steam in degrees of Fahrenheit's thermometer. |
|---|---|
| 1p 75 | 217 deg. |
| 2 .75 | 220 |
| 4 ·55 | 225 |
| 6 .75 | 230 |
| 8 ·55 | 235 |
| 10 ·75 | 240 |
| 12 .90 | 245 |
| 15 .75 | 250 |
| 18 .35 | 255 |
| 20 .85 | 260 |
| 23 .95 | 265 |
| 27 .95 | 270 |

It is not desirable that steam exerting more than a force of four pounds above the atmospheric pressure should ever be employed in laboratories. This steam is produced when the difference of level between the bend of the safety-pipe and that of the water in the boiler is ten feet; but in general a pressure of only two pounds and a-half is used.

In attempting to employ steam of superior force, a great increase of expense is incurred, in the first instance, on account of the various apparatus that must be used to force water into the boiler, and to ensure the workmen, neighbours, and sur-

rounding buildings, from the effect of explosions, which are always to be dreaded when steam of great force is used. The Society of Apothecaries of London use two boilers, one working at about four pounds to the inch, and the other at no less than one hundred pounds. With the last, they prepare sulphuric ether, and also several extracts; but some of the latter are far inferior to those prepared by private druggists, being dry, and as it were, frizzled by the too great heat they suffer when they get rather thick.

The steam itself is used in several different methods.

1st. Sometimes the steam is conducted by a pipe to the bottom of the liquid to be heated, or into the vessel containing the matters to be acted upon by the steam.

2d. The steam is conducted between the outside of the vessel and a cast iron jacket in which it is contained: this jacket has a cock at the lower part to let off the condensed water; as also a cock to let out air.

3d. Or the steam is passed through pipes placed at the bottom of a vessel containing the liquid to be heated.

When the steam is conducted into the liquid to be heated, this latter must be such that the addition of the condensed steam will not have any injurious action upon it. This mode of heating water is attended with a great inconvenience, namely, that the water appears to boil long before it acquires a boiling heat, so that the application of a thermometer is necessary to ascertain whether it really boils or not.

[A still greater objection to this mode of heating by steam, is the great waste of heat; for, as the temperature of the water approaches the boiling point, a very large proportion of the steam which enters the vessel passes through it uncondensed, and of course carries off with it both its latent and sensible heat.]

In the two latter methods, water heated by either of them shows no appearance of ebullition till it actually boils. And they are also attended with another convenience, in that the process may be so conducted that the liquids in the vessels may be preserved for any specific time, at any given temperature between the boiling heat of water and that of the atmosphere, by having indexed cocks fitted to the pipes that supply each particular vessel from the main steam pipe, and admitting only the necessary quantity to produce the desired temperature.

The vapour-bath, or steam apparatus, partakes along with the water-bath the advantage of not allowing thick mucilaginous matter, or sediment, to become burnt; which it is in many cases difficult to avoid with a naked fire.

Parkes, in his Essays, informs us that twenty gallons of water in a copper vessel heated externally by steam, was brought to boil, in one instance, in eleven minutes, and in another in thirteen; but he has omitted to state the

force, and consequently the temperature of the steam. The difference in time arose, he supposes, from the condensed water having, in the former case, been occasionally taken away by turning a stop cock in the most depending part of the jacket; for this being omitted is found to retard the heating of the liquid.

Mr. Taylor informs us, that when a coil of 280 feet of leaden pipe, one inch and five-eighths in diameter on the outside, was laid down in a copper boiler of about eight feet diameter, in which eight barrels of wort were usually boiled, so as to cover and rest on the bottom, and steam of the force of forty pounds to the inch, having, of course, the temperature of about 280 degrees Fahrenheit, was admitted into this coil, ten barrels of wort were brought to boil strongly in fifteen minutes, and were evaporated to six barrels in an hour's time.

That no part of the heat of the steam may be wasted, all the exposed parts of the boiler, the steam pipes, the cast iron jackets in which the boilers are contained, and the conduit pipes for the condensed water, ought to be closely enveloped with bands of straw, and plastered over with mortar, or enclosed in double walls.

The great advantage of a steam apparatus is the quickness with which a vessel filled with water is brought to boil, by merely turning on the steam into its jacket; to which may be added the avoidance of the dust and filth of the fire. These advantages are counterbalanced by the original expense of erecting the apparatus, and the great consumption of fuel, if all the steam produced is not brought into use. Hence this method of heating is only practicable with economy in dye-houses, calico-printing works, and similar establishments on a large scale.

The main steam-pipe in ordinary steam apparatus, ought to have a cock at its farther end, which, like that next the boiler, should not shut quite close, but always allow the escape of a small quantity of steam. This cock is to be opened when the steam is first let into the main, to allow the air, which the steam drives before it, to escape, and when the steam appears the cock is shut. In like manner each of the cast iron jackets must have a similar blow cock to let out the air when the steam is first let into them; and to let it in again when the steam is shut off, as well as a cock or pipe to carry off the water of condensation.

As the heat that escapes from the sand-pot is brought into use by the construction of a sand-bath behind it, so chemists have from the earliest times made use of the heat that escapes from the common boiler or still.

In many chemical works, a plan is adopted of heating water, or other liquor, in a boiler placed on a mass of masonry, or arches, somewhat similar to the manner of the sand-heat, and connected with the boiler by a pipe with a cock; and when the liquor in the still, or first boiler, is done with and removed, the cock is turned, and that in the second boiler supplies its place.

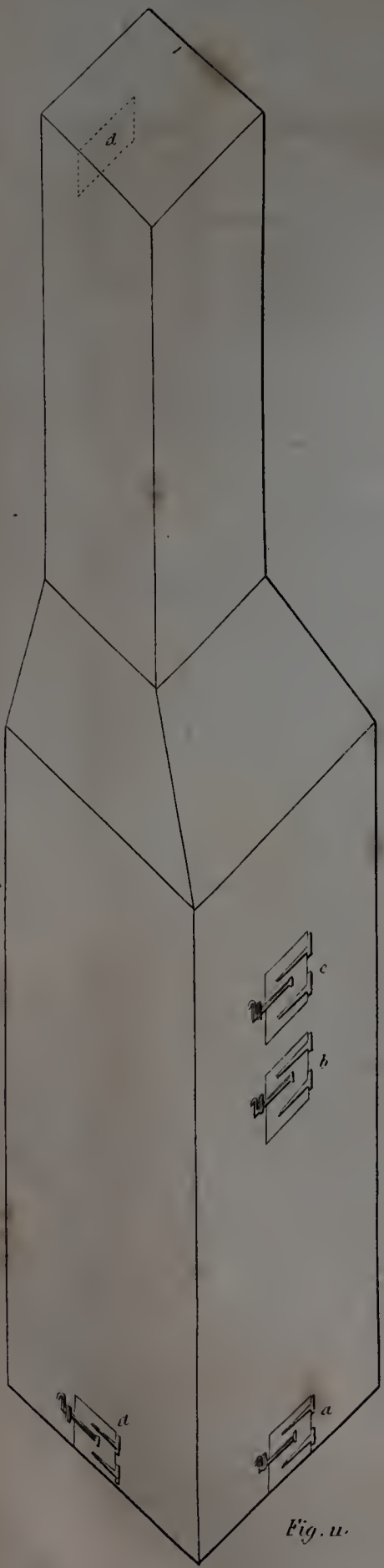
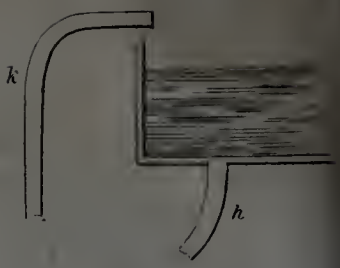



Fig. u.

Fig. g.



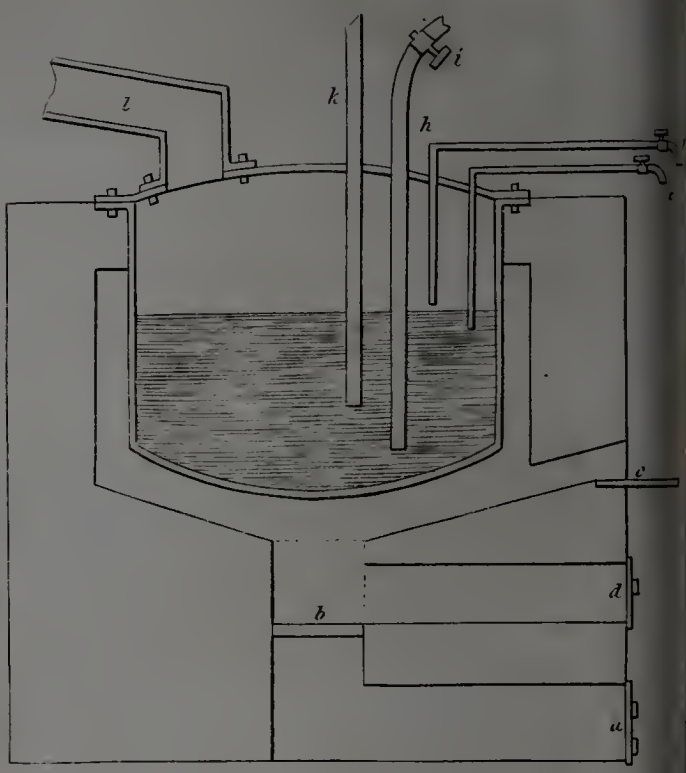
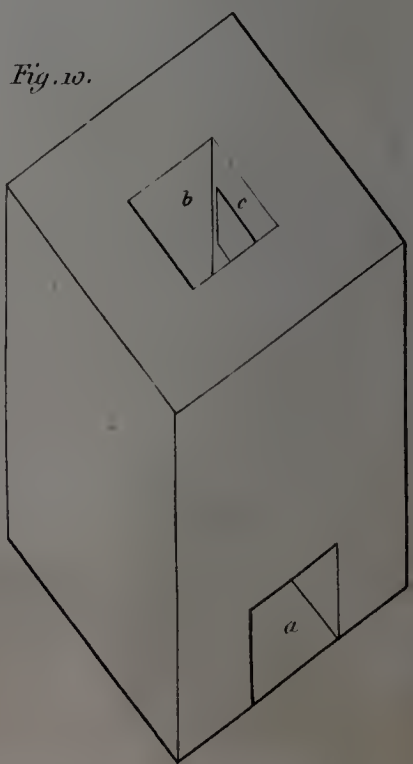




Fig. 10.




0 1 2 3 4 5

The great brewers have even endeavoured to turn to use the heat that escapes through the covers of their boilers, and have surrounded the cover with an upright ledge, so as to form a kind of cistern, or, as they call it, a dome and a baque, vulgarly spelled *back;* but the word is really a French term for a large tub, as its diminutive, baquet, is for a small tub, or pail. When the boiler is emptied, the water thus heated over the other is let in, and thus the time of boiling is abridged.

Mr. Moult, in 1815, took out a patent for employing not only water and sand as baths to transmit heat, but also linseed oil, quicksilver, oil of vitriol, and other liquids, or easily fusible substances. He connected the bath itself with a distilling apparatus, and thus either collected the condensed vapour for use, or caused it to return into the bath.

In using linseed oil as a bath, he collects the portion that is evaporated, and employs the same oil repeatedly for a bath until it is sufficiently boiled to become painter's boiled oil.

## *The Melting, or Founder's Furnace.*

A furnace is required in laboratories for melting metals, without the labour of blowing, and is usually called the melting, or founder's furnace. It has this inconvenience attending its use, that it requires nearly an hour before it acquires its full power; but the heat is more steady than that of the blast furnaces.

Its construction is remarkably simple.

Fig. 10, represents this furnace, drawn on a scale of half an inch to a foot.

That the operator may be complete master over his crucibles, the grate is placed nearly on a level with the ground, the ash-room, *a*, being only about six, or at most nine inches above it, open on both sides, but close in front. The fire-place is generally a rectangular prism, the internal cavity, *b*, having its sides of nine inches, and its depth twenty-four. Two rows of bricks are merely laid parallel to each other, at nine inches distance, to form the front and back of the ash-pit. Upon these are placed two strong iron bars to support the fire-bars, and another course of bricks laid, leaving space for the reception and expansion of the bars.

Two broad iron bars are then laid a little above the fire-bars, to support the sides of the fire-place, which is continued up of bricks capable of bearing the fire. In the back of the furnace is left a vent, *c*, usually four inches high and seven wide, which, being covered over, communicates with a chimney into which no other furnace opens.

The cover of these furnaces is usually made of an iron case, lined next the fire with clay and charcoal, and having a handle.

The grate is composed of four or five loose iron bars, an inch square, which are laid sometimes closer, sometimes more open, by taking one out, or putting one in, as is judged proper to regulate the draught.

By the entrances for the air being on the sides, the radiant heat from the bottom of the fire is prevented from incommoding the operator as he stands in the front of it, and the fire-bars being loose, when they are burned, the furnace is not required to be pulled down to replace them.

Charcoal is the best fuel for this furnace; if coke be used, it forms clinkers in a violent heat, which clogs up the fire bars, and requires them to be continually cleared by a fire-hook, and those adhering to the sides, occasionally removed by a four-foot poker, terminating in a three-inch chisel edge.

Chenevix proposed to make this furnace three inches wider at bottom than

at top; but this is unnecessary, for the crucibles themselves being narrower at bottom, allow the fuel to descend with ease.

The founders usually make these furnaces of a cast-iron cylinder of fourteen inches diameter internally, and eighteen high, having a notch, of sufficient size for the vent into the chimney, cut in the upper edge. When set up, they line it two inches thick with the black sludge obtained from the grinders of looking-glasses. This sludge consists of grinding-sand, intermixed with particles of glass, and conglutinates by heat into a solid mass.

The ash-pit is usually sunk into the ground, made very large, and the air admitted into it through a grate, on which the workman stands. Sometimes, to have still greater command over heavy crucibles, the fire-place itself is sunk so that the mouth is level with the floor, and a crane is placed so as to be capable of being brought over the mouth of the furnace, for the purpose of taking out the crucibles, or turned on one side to set them on the floor.

## *The Air, or Wind Furnace.*

The lowness of the last furnace is advantageous for the management of crucibles, or melting-pots; yet, when cupellation, or calcination, is to be performed under a muffle, in which operation a frequent and indeed almost constant inspection is necessary, the muffle in the fire-room must necessarily be nearly on a level with the eye of the operator, as he sits before the furnace. And when substances are to be distilled in small quantities, with the utmost extremity of fire, the retort must be placed in a wheel-fire, and, of course, the fire-room raised of a sufficient height to admit of the necessary receivers being attached to the distilling vessel.

For the advantageous performance of these operations, the fourth furnace of Glauber, with a high flue, invented, as he ingenuously tells us, through mere necessity, he not having at the time money sufficient to buy a pair of forge-bellows, and which is called an air, or wind-furnace, is usually employed.

Fig. 11, represents this furnace on a scale of half an inch to a foot. The ash-room is a hollow prism, twelve inches square, with walls nine inches thick, and about three feet high. An opening, *a*, of about six inches square, is left at the bottom of one or more of its sides, each to be closed with an iron door. Two strong iron-bars are placed across the top of this ash-room from front to back, and about six inches apart. On these are laid six iron-bars, nearly an inch square, and scarcely more than eleven inches long, with their ends hammered up so as to keep them near an inch asunder. The walls of the fire-room are continued up to the height of three feet above the upper surface of the grate, of Windsor or other fire-bricks set in the loam of which they are made. Two openings, *b*, *c*, are to be left in the front, one above the other, each eight inches high and six wide; the lower edge of the lower opening is to be level, and between two or three inches above the grate, so that if a brick be placed on the grate, the whole may form an even surface.

This lower opening is to insert a muffle, retort, or crucible into the furnace; the upper opening, *c*, placed about three inches above the former, and of the same size, is partly used to feed the fire, and partly to inspect the condition of the matter in the crucible. Both these openings are to have stoppers or doors fitted to them.

The furnace is then contracted at top, by having its walls made only four inches and a half thick, and built up as high as the laboratory will allow, when it is to be closed at top, a vent-hole, *d*, being left in the back wall, which is generally four inches by nine, or six inches square, opening into the chimney.

This furnace, like the preceding, requires a strong draught of air to produce its full effect. When it is used for calcinations or other operations under a muffle, a brick cut sloping on the farther end and sides, that it may intercept less of the air, is placed on the grate. On this the muffle or arched earthen oven is put, and the remainder of the lower opening is closed up with pieces of bricks and clay; the mouth of the muffle is also closed with a loose brick.

In distillation with a wheel-fire, a piece of brick hollowed at the top is placed on the centre of the grate to support the retort, the neck of which projects through the lower opening, and the remaining space is closed with bricks and clay.

As this furnace will, from its large fire-room door, admit the introduction of crucibles, it is in more common use in the laboratories of druggists than the preceding, and is used by them to supply the place of the melting furnace; for although it will not, as generally constructed, produce so great a degree of heat, yet its power is sufficient for most purposes; and it is useful in several other respects.

Fig. 12, represents a geometrical elevation of a furnace of this kind on the same scale of half an inch to a foot, as it is ordered to be built by Boerhaave, on a hearth raised about three feet from the ground. The furnace is made by him circular; the diameter on the inside to be twelve inches, and the walls five inches thick. The ash-room to be about six inches in height, with an iron door fitted to it. The walls are continued upright to the height of two courses, or six inches above the grate, *b*, after which the inside cavity contracts gradually in the form of a parabolic conoid, so that the internal cavity of the furnace may be terminated at the height of fourteen inches above the grate, by a circular vent-hole, *c*, three inches in diameter, opening into a short chimney, *d*, only two feet high, having a circular flue of the same diameter. This short chimney was then connected with the main chimney.

The professor has, of course, room only for one door, *e*, five inches wide, and six high, above which he orders a conical opening to be made, one inch in diameter, next the inside of the furnace, but wider externally, for the purpose of looking into it. To this he fitted a stopper.

This furnace is indeed much smaller than those of the common construction, and requires a skilful mason to build it; but the power it possesses is considerable.

In using it with a muffle or retort it would be necessary, in stopping up the fire-room door, to leave a hole as large as can conveniently be done for feeding the fire; and it is best to place two entrances to the ash-room on the sides.

M. Beaumé, instead of contracting the vent at the top, run up the walls quite straight, to the height of fifteen feet above the grate. His furnace was thirteen inches from front to back, and ten inches from side to side in the interior. The ash-room was open on all sides to allow the freest possible access of air: and he avers that the furnace thus constructed produced the greatest heat ever known.

## *Boerhaave's Reverberatory.*

A chemical laboratory must also necessarily have a particular furnace for distilling the mineral acids, as those of sea-salt, nitre, alum, vitriol, or any other distillations which require a stronger heat than can be given in the sand-pit.

After several trials, Boerhaave has recommended the following as fittest for the purpose, which is represented in Fig. 13, on a scale of half an inch to a foot.

Upon the pavement of the laboratory under the chimney, build up a parallelopiped, thirty inches broad in front, *a b;* and forty inches long from *a* to *c*. Let the cavity be twelve inches wide in front, and twenty-two inches long, which gives one brick, or nine inches, for the thickness of the wall. Let the parallelopiped be raised eleven inches high; make a door-way, *d*, in the middle of the front, rising eleven inches from the ground, and four inches wide, leaving an indenture in the front of the furnace to receive an iron-door, and let in close occasionally.

This part of the apparatus regards the ash-room of the furnace and entrance for air. Instead of a grate in one piece, here use prismatic iron bars, an inch wide and fourteen inches long, placing them an inch asunder, parallel with the breadth of the ash-room, and support them by two strong bars. Then build up the walls on all the sides fifteen inches in height.

In the front wall, immediately over the ash-hole, make a door-way to the fire-place, *e*, seven inches wide, and nine inches high; and let this door-way be exactly fitted with an iron door, the lower line of which is three inches above the upper line of the ash-hole.

In the middle of one of the long sides or front there must be an arched opening, *f*, with its lower limit rising ten inches above the grate, and being twenty inches long and twelve inches high.

This opening is for the distilling vessels to be put in and taken out at. On the internal side, opposite to this opening, at the height of nine inches above the grate, a ledge of an inch and a half must be left in the back wall, to support the vessels employed in the distillation; and in the middle of the upper part of this back wall there must be a square hole, three inches wide, and two high, for the vent of the chimney.

The furnace must then be roofed over with an arch springing from the front to the back, so that the height of the centre may be twenty-one inches above the grate.

When this furnace is used for distillation, two cylindrical earthen or cast-iron long necks, having cylindrical necks five inches long, and three inches and a half in diameter, are to be placed horizontally and parallel to each other, so that their bottoms may rest upon the ledge in the opposite wall, whilst their mouths lie parallel to the opening, *f*, they are put in at. The opening, *f*, is now to be perfectly closed up with brick and clay, leaving the necks of the vessels sticking out, to which earthen pipes or adopters being applied, and their other ends fixed into receivers, the operation may be thus begun. These receivers ought to be of a conical shape; for as only a very slight lateral deviation can be given to the cylinders, the great breadth of globular receivers of the same capacity would be inconvenient.

This furnace will raise a surprising degree of heat, and is at the same time safe and easy to manage. It likewise directs all the force of the fire upon the subject to be distilled, and may easily be regulated by means of the ash-hole. The learned professor informs us, that on trying to use cast-iron cylinders for the distillation of phosphorus from urine, he found they melted long before he had reason to expect the phosphorus

Fig. 12.

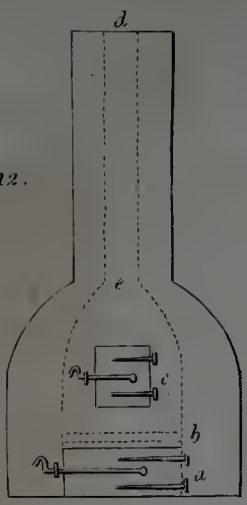
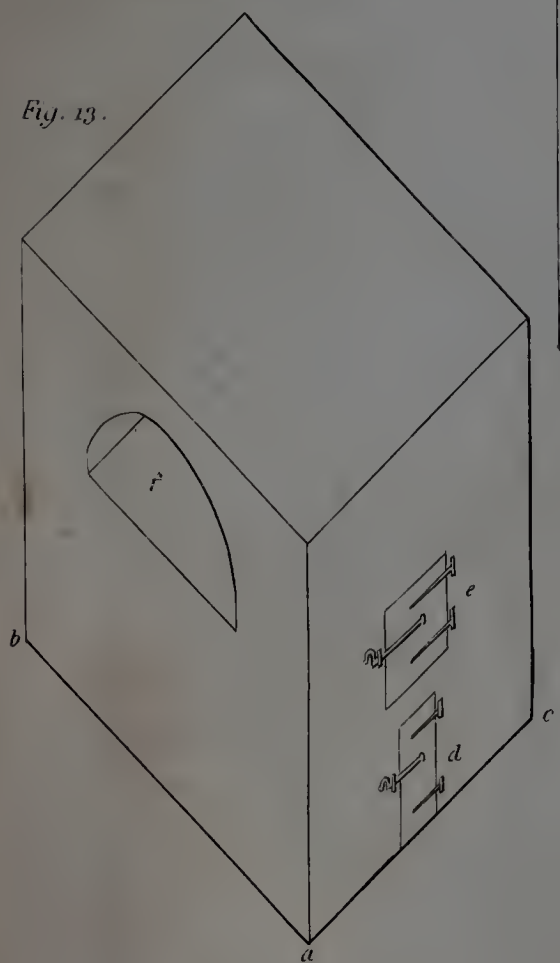
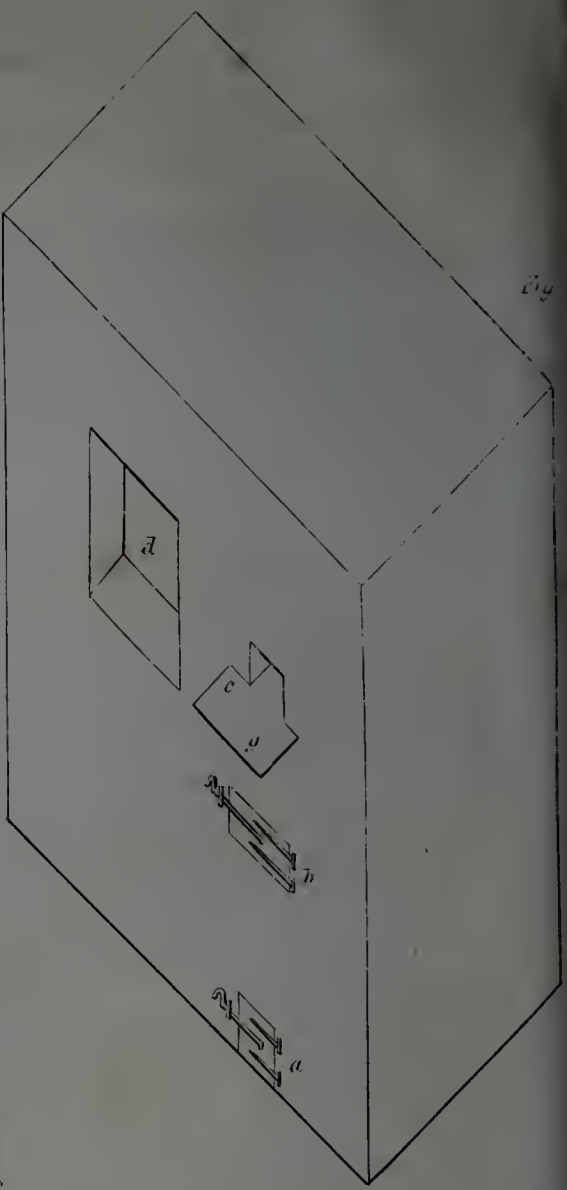



Fig. 13.



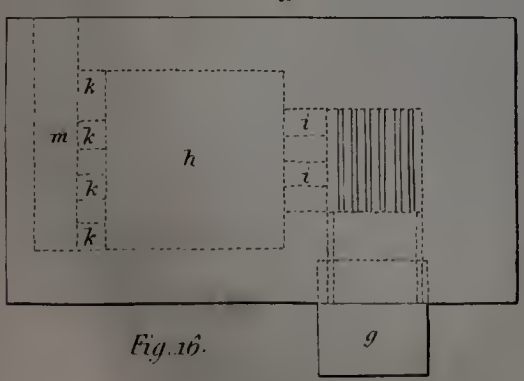




Fig. 16.

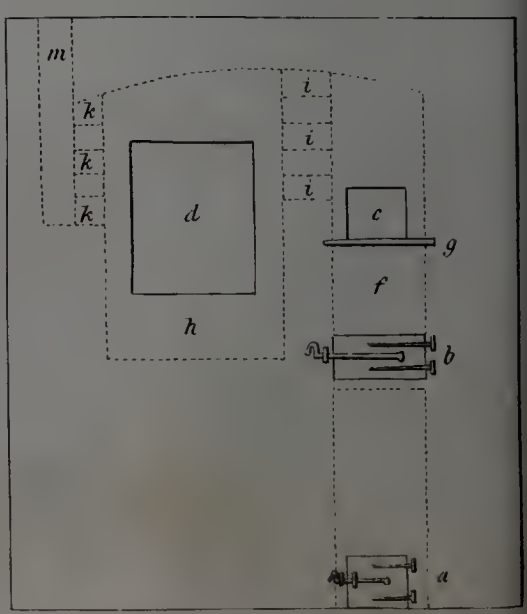



Fig. 15

0 1 2 3 4 5 feet

to come over, whence we may form some judgment of the heat that this furnace will give when charcoal is used as the fuel.

Furnaces constructed upon the same principles as this reverberatory furnace invented by Boerhaave, are come into very common use, for various purposes, as will be seen in several parts of this work. They are used, for example, in preparing the nitric, muriatic, and pyroligneous acids, charcoal for gunpowder, gas for lighting rooms, and in several other instances.

### *Reverberatory-Furnace, with a side Chamber.*

Another kind of reverberatory-furnace, with a chamber on the side, has been long in use in the mining countries, but was first attempted to be brought into the general laboratory by Cramer, the operator of Boerhaave, who published his Elementa, Artis Docimasticæ, as a supplement to the Elementa Chemiæ of his master. But as he conjoined it with a tower muffle-furnace, a sand-pot, and water-bath, the construction of the furnace was so complicated, that although it has been described in several English books on chemistry, there is reason to believe the furnace described by him has never been built in England: it is, indeed, a true Dutch toy, requiring to be built and attended by the chemist himself, as neither bricklayer nor any hired operator would enter into the minutiæ of its construction, or its management when in use.

Dr. Bryan Higgins discarded the additions of Cramer, and simplified its construction. In my Elements of Pharmacy his large reverberatory is described, the present is his small furnace of that kind, as it existed when I first went to his assistance as operator.

Fig. 14, represents this furnace in perspective, which is about four feet two inches wide, two feet three inches from front to back, and four feet nine inches high.

Fig. 15, is a geometric elevation of the front.

Fig. 16, is a plan,—all drawn on a scale of half an inch to a foot.

The ash-room, *e*, and fire-room, *f*, are prismatic cavities of nine inches square, with walls of the same thickness, having the ash-room entrance level with the ground, with a door six inches square, and a stoking-door, *b*, nine inches wide, and four inches high, just above the grate, which is one foot nine inches from the ground. Above the stoking-door is a feeding-door, *c*, five inches wide and four high, with a square ten-inch slab, *g*, of cast-iron, to support the small coal used for stopping it. All these openings may be either in the front or side of the furnace.

The chamber, *h*, is separated from the fire-room by a wall, half a brick, that is, four inches and a half thick, which has, towards the roof of the furnace, several holes, *i*, two inches square, placed in quincunx, or chequer-ways, through which the flame and heated air passes into the chamber. Its ground-plot is eighteen inches square, and its floor two feet from the ground: the front and back walls are four inches and a half thick, but that opposite the fire-room, a whole brick, or nine inches thick. An opening, *d*, fifteen inches high and

twelve wide, is to be left in the front wall of the chamber, the lower edge being two feet six inches from the ground, and the opening surrounded by a frame of flat iron bars.

In the substance of the side wall of the chamber, opposite the fire-room, a channel, *m*, is made, into which a number of vent-holes, *k*, similar in size and number to those which conveyed the flame, &c. into the chamber, at the other end open; and this channel opens into the flue of the chimney.

To use this furnace with retorts, bricks are put into the chamber to form a support for them, and the large opening through which they were introduced is then closed with pieces of brick cemented with clay, or if no great heat is intended to be used, with moistened ashes.

If the substance to be distilled is apt to froth when heated, the fire must be applied from above downwards; in this case, the retort being fixed upon bricks, the remainder of the chamber up to the level of the substance in the retort is to be filled with sand, and when the large opening is filled up, two holes are to be left, one at each of the corners. The fire being then applied, and the distillation begun, the sand is to be gradually drawn out by an iron hook through these holes, by which means the retort is gradually uncovered as the distillation advances, and the vapours have not got to force their way through a mass of cool matter.

Crucibles with compositions for glass or pastes, seggars with pottery or porcelain-ware, cement-pots, calcining-dishes, or bone-ash tests for cupellation, may be placed in the chamber on a false floor of bricks; also a large muffle, or enamel kiln, and the opening bricked up, leaving one or two apertures for taking out trial pieces, or for inspecting the work.

Although this furnace is so useful, it is seldom found in general laboratories, but it is to be expected that its merits will be properly estimated, and that it will in future come into common use.

Several varieties of this furnace are employed for roasting and smelting ores; and for calcining kelp and other salts.

### *The Forge.*

The forge and blast furnace are usually confounded together, although in fact very different.

The proper chemical forge, represented in Fig. 17, drawn on the scale of half an inch to a foot, is a massy piece of brickwork, *a*, about three feet square and two feet high, the back part of which has a wall, *b*, of half a brick in thickness, raised up about eighteen inches higher.

On the upper part of the hearth, next the brick wall, there is a square pit, *c*, of twelve inches square, and six inches deep. A channel, *d*, of about two inches square, leads from the middle of the bottom of this pit, sloping to the front, where it opens about three inches from the ground.

The back wall has a twere hole, *e*, being a long narrow slit of the width of the twere-pipe, and so high as to allow this to be placed at different angles, so

Fig. 17.

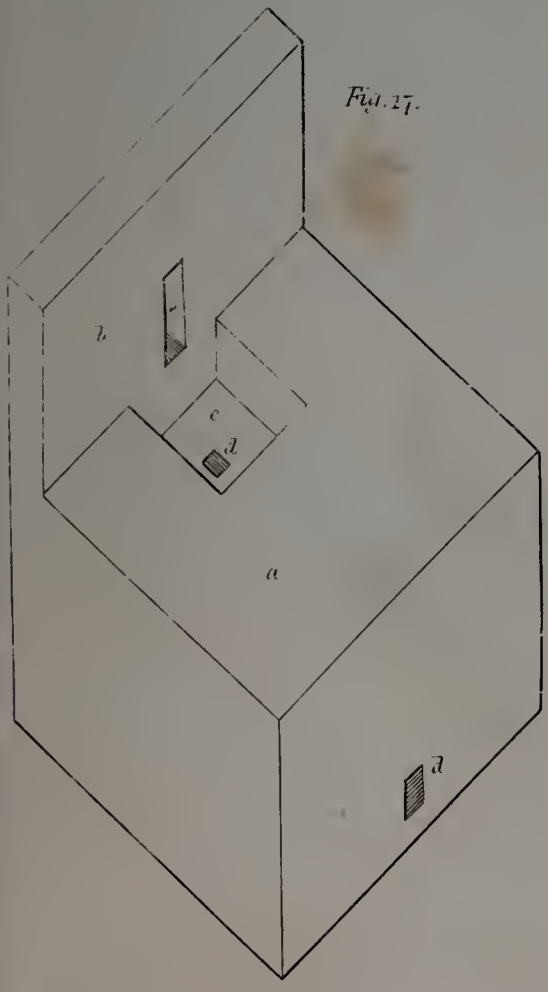
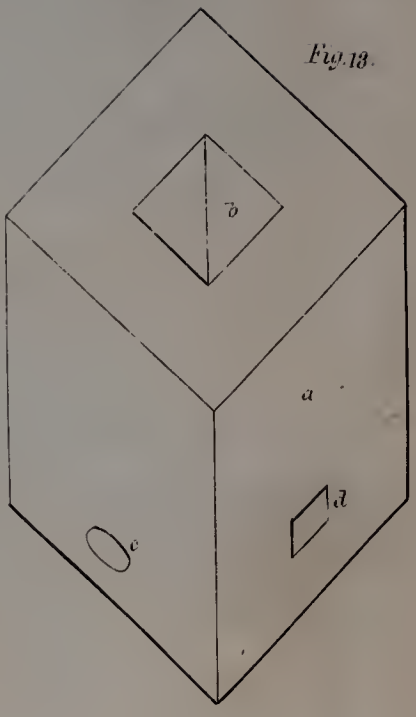
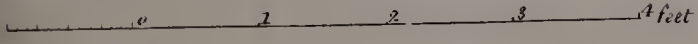



Fig. 18.



as either to blow horizontally over the whole surface of the hearth, or at an angle of such obliquity as to direct the blast to the lower edge of the pit.

In the most general use of the forge, the pit is filled up with bricks, and the blast directed horizontally on the flat hearth. When caking-coal is used for fuel, care is taken to preserve a large cake to serve as a kind of vault to reverberate the heat; and to encourage the coals to cake, they are occasionally sprinkled with water.

The forge is sometimes used to melt substances in crucibles; two are in this case usually employed, and they are set upon a piece of brick about an inch high, not exactly opposite the blast, but so that it may pass between them, and the heat is confined by a few bricks being placed at a little distance, so as to form a semicircle.

In some operations on metals, the pit of the forge is filled with moist clay, mixed with charcoal powder into a stiff mass, and a hemispherical hollow, of about eight inches diameter, is formed in it. This is dried by making a small fire in it, and then, when sufficiently heated, the ore, or metal is added. After the operation is over, the materials are either laded out, or left to cool in the pit, or a hole is made with a poker, in the bottom, and the metal is allowed to run through the channel into a vessel placed in the front of the forge for that purpose. In this mode of operating, the twere-pipe is directed downwards, with a greater or less slope, as circumstances direct. The more it slopes the stronger is the heat.

The forge is frequently used to kindle a fire in a hurry, and is superior to any close furnace when vessels and materials require to be taken from the fire quickly, and as speedily replaced. It requires to be placed under a hood, or chimney, to carry off the smoke and vapours.

## *Blast Furnace.*

The blast furnace agrees with the forge in being supplied with air by means of double bellows, but it has a grate, or a plate with holes serving for the same purpose.

The blast furnace is represented in Fig. 18, drawn on a scale of half an inch to a foot, and is externally of a cubical form, *a*, about two feet and a quarter each way. As the walls are a brick thick, the internal cavity, *b*, for the fire, is nine inches square, or, which is still better, circular, and about ten inches over, and goes down within three inches, or a single course of bricks, from the ground. The round furnace is usually made bellying in the middle to allow more room for the crucible.

There are two openings made at the bottom into this furnace. The first, *d*, is in the front of the furnace, about three inches square, and furnished with a piece of brick fitted to it. The other hole, *e*, is on the side, about six inches from the ground, to admit the blast pipe from the bellows.

When this furnace is to be used, an iron trivet, about eight inches high, is

to be put down the mouth of the furnace; and on this is to be placed, if the fire-room is circular, a cast iron plate with a double circle of round holes, one inch over; or if the fire-room is square, a grate, the bars of which are to be an inch wide, with spaces of the same width between them. A block of brick is placed on the grate, and on this is put the crucible; the furnace is then filled with fuel, and, being lighted at top, the door at bottom is left open until the whole of the fire is lighted and the crucible properly annealed.

The entrance for air is then closed by the brick and some moist clay, the mouth also partly closed by a couple of bricks to confine the heat, and the blast let on at first gently until the operation is nearly finished, and at last a strong blast of the utmost power of the bellows is usually given for about a quarter of an hour.

This furnace is not much used in small laboratories in England, and the founder's furnace is generally preferred in its room, partly on account of the trouble of blowing. The blast furnace has, however, some advantages, such as its not requiring a high chimney, which will frequently oblige a chemist to have recourse to it for exciting a great heat.

As soon as the bellows of small blast furnaces cease working, a cock, placed for that purpose on the blast-pipe, should be shut to prevent the hot air from rising into them, and causing the leather to crack.

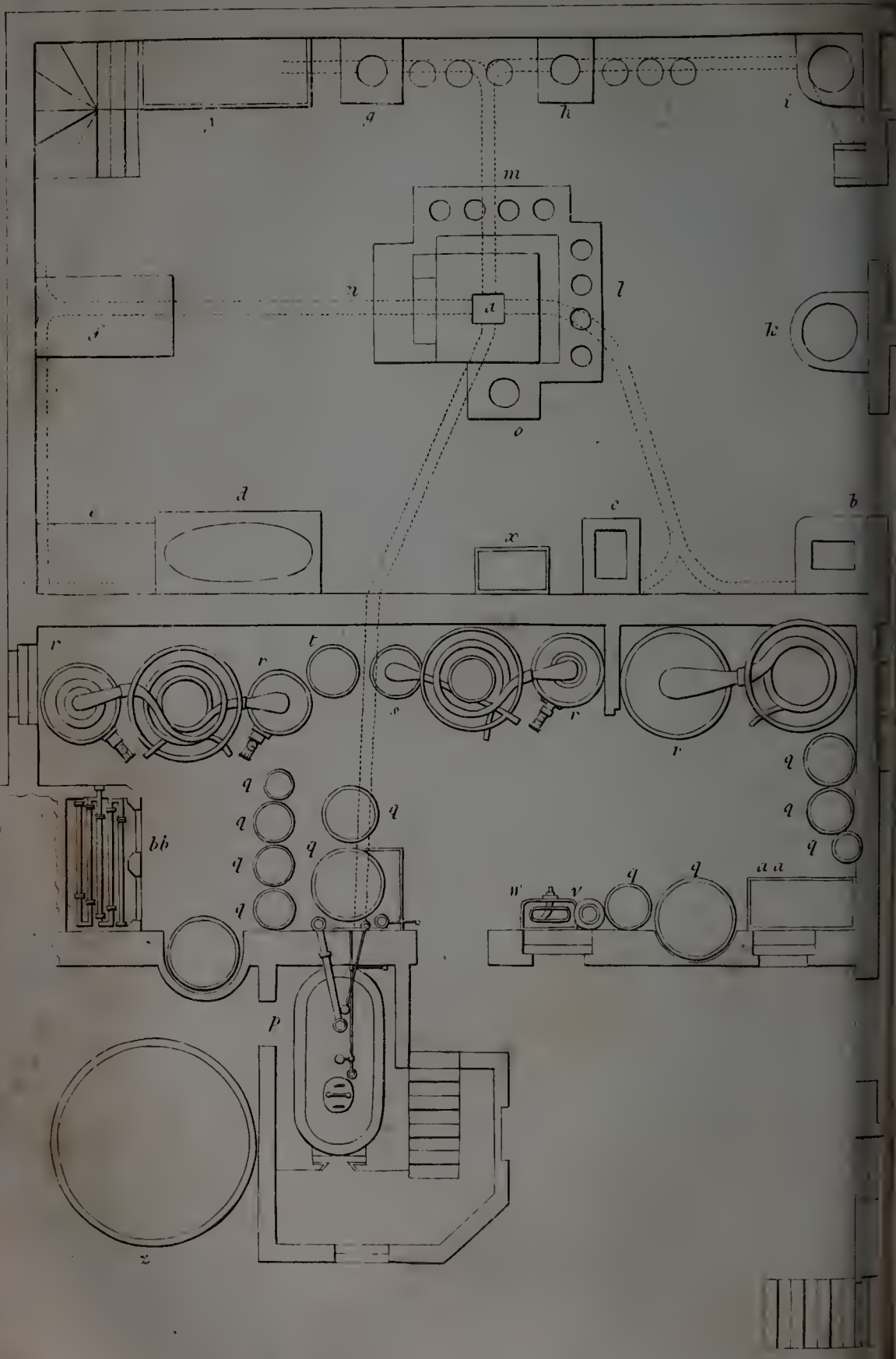
The forge bellows must either be placed in a frame so constructed that they may be raised and lowered at pleasure, or if they are fixed in the upper part of the laboratory, which is most usually the case, in order that they may be out of the way of the operator, then the pipe must be made for some length, of leather hose, that its flexibility may allow the end to be altered in its height: in either case, the handle must be to the left of the operator.

In metallurgy on a large scale, the blast furnace is frequently used, and is, by the iron masters, made of an enormous size, even to that of seventy feet in height.

### DISPOSITION OF FURNACES IN A LABORATORY.

Authors on chemistry do not often give any directions or plan to lay out a laboratory, nor show the mode in which fixed furnaces are connected together, when the chemist intends to devote a room for general chemical purposes. A few authors, however, have not omitted this very necessary information, and have given plans, elevations, or views of their own laboratories.

The principal difference consists in the dispositions of the chimneys. Barchusen, Pepys, and Thenard, place all their furnaces against the wall, under hoods, and the two latter have separate flues and chimneys for each furnace, or for two or three at most. Dr. Higgins, and the Society of Apothecaries, place the chimney in the centre; the first using several separate flues, the latter one single flue for all the furnaces.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*London Society of Apothecaries' Laboratory.*

The principal laboratory is a brick building, (Fig. 19.) about fifty feet square, and thirty high, lighted from above, and subdivided, by a brick wall, into two compartments. The dimensions of the larger one being fifty feet by thirty, and of the smaller, fifty feet by twenty. The former may properly be termed the Chemical Laboratory, all the open fires and furnaces being situated in it, and all operations requiring intense heat being there conducted. The latter is usually termed the Still-house, all distillations and evaporation being performed there exclusively by steam, most of which is furnished by a boiler placed in a small building annexed to the main laboratory.

The principal entrance to the Chemical laboratory is through the mortar-room, which is forty feet long and twenty-two broad, and appropriated to mortars, presses, and, generally speaking, to all mechanical operations performed by manual labour. At its eastern extremity is a large drying-stove, heated by flues, for the desiccation of those articles which cannot be dried conveniently at temperatures easily obtained by steam.

In the construction of the new laboratory, safety is ensured, as the whole is made fire-proof, by being lined with sheet-iron wherever it is necessary, and it is ventilated by a series of apertures in the roof, which may be opened or closed at pleasure. The main chimney, *a*, is erected in the centre; and has opening into it below the pavement of the laboratory, four large flues, one of which enters upon each side of its square base. The shaft is one hundred feet high from the foundation, and is accessible in its interior, from one of the under-ground flues. The flues of the furnaces, which are placed against the walls of the laboratory, are each supplied with registers, and open into a common channel which surrounds the building, terminating in the chimney, as already described. Each of the four large flues has also a register, which may be more or less closed or opened, according to the operations which are going on in the various furnaces connected with it.

The furnaces thus arranged, are,

*B*, a subliming apparatus for benzoic acid.

*C*, a furnace for the preparation of sulphate of quicksilver, with two descending flues communicating with the chimney; one for smoke, the other to carry off the sulphurous acid.

*D*, a high pressure steam-boiler.

*E*, a muffle-furnace was originally placed here, but it has been taken down, and a cistern of hot water supplies its place.

*F*, a large sand-bath, to work with several retorts at once.

*G*, an apparatus for distilling muriatic acid, with a file of three receivers connected together.

*H*, an apparatus for distilling nitric acid, with a file of three receivers connected together.

*I*, an apparatus for the distillation of hartshorn, with a cast-iron condenser.

*K*, a circular calcining furnace, as it is called by Mr. Brande, but which is in fact nothing but a large stove-hole, about three feet in diameter, without either vent into the chimney, flue, or even a hood over it. This hole is used to calcine magnesia, but as it is heated partly with raw coals, it so fills the laboratory with smoke, that the fire is only lighted in the evening, when the operators leave off work, and left to itself.

There are also a series of furnaces built against the sides of the main chimney, and communicating directly with it, by flues of their own, which, as well as the common openings by which they enter the chimney, are supplied with effectual registers, so that when not in use, they may be perfectly closed. Of these furnaces, eight, *l*, *m*, are chiefly employed for various sublimations and fusions, or for retort pots; the third side of the chimney is occupied by a powerful wind-furnace, *n*, and the fourth by a furnace, *o*, for the sublimation of calomel.

The steam laboratory is supplied from two boilers, the largest of which, *p*, placed in a building separate from the laboratory, is an eight hundred gallon boiler, of the common wagon shape, made of copper, and works an engine of eight-horse power, at a pressure of an atmosphere and a half; consequently the steam produced by it has a temperature of 230 degrees. A forcing pump is also annexed to the engine, by which the boiler is occasionally supplied with hot water, resulting from the condensation of the steam in the various vessels.

The main steam pipe, which is six inches in diameter, is conducted round the laboratory in a cavity of brick-work, covered by moveable cast iron plates, and is accompanied by a smaller pipe, which receives and conveys the water resulting from the condensation of the steam into a cistern properly supplied with valves, whence it is occasionally pumped back into the boiler. A small steam pipe, with a register cock, passes to each of the stills and evaporators, each of which sends off a condensed liquor pipe into the main for its reception.

Four of the twelve boilers and evaporators, *q*, are of pewter, one of iron, and seven of copper. Four of these boilers are capable of holding from 150 to 300 gallons each; four contain about one hundred gallons each; and four from ten to twenty gallons each. There are also some smaller vessels of the same kind generally used as water baths.

The stills are seven in number; four are of copper, *r*; of these the largest contains five hundred gallons, and has a distinct worm tub; two contains two hundred gallons each, and one contains 150 gallons. There is a pewter still, *s*, of about thirty gallons, and one of lead, *t*, for the distillation of ether. These five stills have two condensing tubs; lastly, there is a still, *u*, which with its head and worm, *w*, are entirely of stone ware: it is chiefly employed for distilling spirit of nitric ether.

With the exception of the leaden ether still, all the above vessels are heated by the circulation of steam upon their exterior, being enclosed in cast iron jackets, and having a space between the two of about half an inch in width, into which the steam passes from the main steam pipe by the register cocks, and from which the condensing pipes pass off. A blow cock is attached to each vessel to allow of the escape of the air when the steam is first turned on.

A large branch of the steam pipe circulates in five convolutions at the bottom of the drying stove, *b b*, so as to heat a current of air, which is made to pass through it, and another branch, rising perpendicularly through the pavement, is properly fitted with cocks and screws for the occasional attachment of leaden or other pipes for boiling down liquids in moveable pans and vessels.

The small boiler, *d*, in the laboratory, is calculated for the production of high pressure steam, with a pressure of a hundred pounds on the square inch, so that the temperature of the steam produced by it is very considerable. It is

applied in another part of the building to various purposes of evaporation, solution, decoction, &c. and in addition, it only supplies the ether still in the steam laboratory, which is heated by a coil of leaden pipes, by which the temperature requisite for the production of ether from alcohol and sulphuric acid is obtained.

The waste steam of these boilers is condensed into a large cistern of water in another part of the building.

Besides the distillatory and evaporatory apparatus there are also two large drying stoves heated by steam, and several wooden and other vessels for saline solutions, &c. which are occasionally adapted to the steam apparatus, and heated by a coil of leaden pipe.

*X*, is a sink with a supply of water.

*Y*, is a collection of coal and coke bins, for the immediate supply of the laboratory.

*Z*, is a gasometer, to collect the oil gas, which is made in another part of the building.

*A a*, is a marble table in the still-house.

Besides these two laboratories the society has also under the same roof, what they call a test laboratory, on a smaller scale, which cost about six hundred pounds to build; although it contains only a square sand-bath, a single stove hole, and a raised hearth paved at top with Dutch tiles, and having several gas-burners, over which are placed the retorts and other vessels supported on the common pillar-and-ring stand.

They have also a magnesia room, with four copper and three iron boilers, and several large vats for dissolving, precipitating, or crystallizing saline solutions.

The plan and description of these laboratories are sufficient to show that they are by no means so well constructed as might be expected. As to the steam laboratory, it can only be regarded as a mere show; for pharmaceutical operations do not, like those of the dyeing and printing businesses, require successive rapid boilings of different liquors in the same vessel. The danger of burning-to might have been as effectually guarded against by the use of water-baths when necessary; although not in so elegant a manner, or so compact a compass; but the Society has room enough, for since the unsuccessful attempt made by them to procure the supply of the army, they have lost that of the navy, which they had supplied for rather more than a century, and have let out a part of their premises to a printer.

### PORTABLE FURNACES.

Persons who are not in possession of a sufficient space of ground are necessitated to adopt the use of smaller furnaces, which may be laid away when not in use.

## *Dr. Black's Furnace.*

Dr. Black, Professor of Chemistry, at Edinburgh, invented a peculiarly simple portable furnace, which he used for almost every purpose; but which, notwithstanding its extreme elegance of form, has been much neglected, and inferior portable furnaces have had the preference given to them.

Fig. 20, represents the external form of this furnace, and Fig. 21, a section of it. The body of it is of an oval form, made of thin sheet iron, and closed at each end by a thick cast-iron plate. The upper plate, or end of the furnace, is perforated with two holes; one of these, *a*, is pretty large, and is often the mouth of the furnace; the other hole, *b*, is of an oval form, and is intended for screwing down the vent upon. The undermost plate, or end of the furnace, has only one circular hole, somewhat nearer to one end of the ellipse than the other; hence a line passing through the centre of both circular holes, has a little obliquity forwards. This is shown in Fig. 39, which is a section of the body of the furnace, and exhibits one half of the upper, and one half of the under nearly corresponding holes.

The ash-room, *c*, is made of an elliptical form, like the furnace, but is somewhat wider, so that the bottom of the furnace goes within the brim; and a little below there is a border, *d*, Fig. 39,) that receives the bottom of the furnace.

Except the holes of the damping-plate, *e*, the parts are all made close by means of a quantity of soft lute, upon which the body of the furnace is pressed down, whereby the joining is made quite tight; for it is to be observed that, in this furnace, the body, ash-pit, vent, and grate, are all separate pieces, as the furnace comes from the hands of the workman.

The grate is made to apply to the outside of the lower part or circular hole; it consists of a ring set upon its edge, and bars likewise set on their edges. From the outer part of the ring proceed four pieces of iron, by means of which it can be screwed on; it is thus kept out of the cavity of the furnace, and preserved from the extremity of the heat, whereby it lasts much longer.

The sides of the furnace are luted, to confine the heat, and to defend the iron from the action of it. The luting is so managed, that the inside of the furnace forms, in some measure, the figure of an inverted truncated cone.

To this furnace belongs a crow's foot, *f*, and a cast-iron sand-pot, *g*, with a cover, *h*.

Now to adopt this furnace to the different operations in chemistry, we may first observe, that for a melting furnace, we need only provide a covering for the upper hole, which, in this case, is made the door of the furnace. As this hole is immediately over the grate, it is very convenient for introducing, and examining, from time to time, the substances that are to be acted upon. The cover for the outer door may be a flat square tile or brick. Dr. Black usually employed a sort of lid made of plate iron, with a rim that contains a quantity of luting. The degree of heat will be greater in proportion as we heighten the vent, and to the number of holes we open in the damping-plate.

By this means the furnace may be employed in most operations in the way of assaying; and though it does not admit of the introduction of a muffle, yet, if a small piece of brick is placed upon its one end, in the middle of the grate, and if large

Fig. 20.

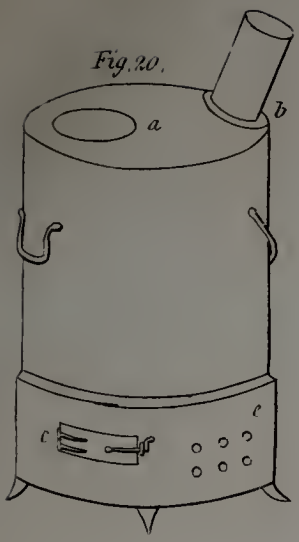



Fig. 21.

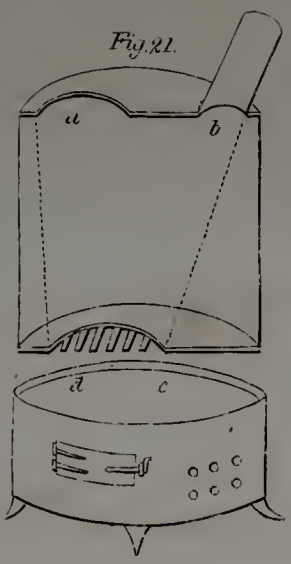


Fig. 22.

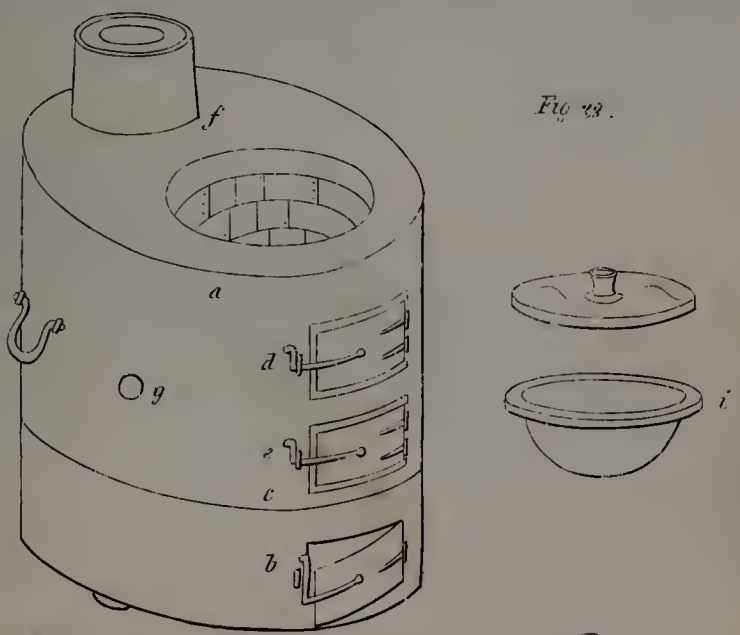
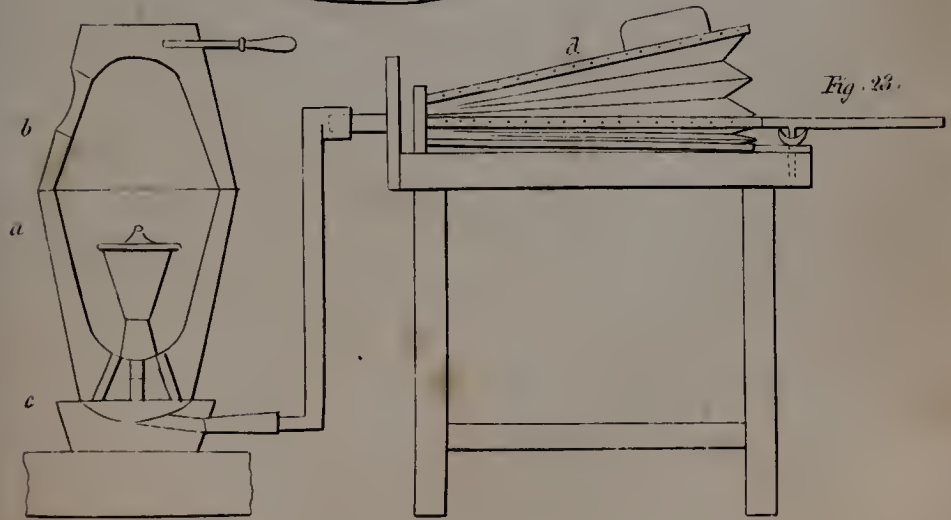



Fig. 23.



pieces of fuel are employed, so that the air may have free passage through it, metals may be assayed in this furnace without coming in contact with the fuel. It may therefore be employed in those operations for which a muffle is used; and in this way, lead, and sundry other metals may be brought to their proper calces.

When we wish to employ this furnace for those distillations requiring an intense heat, an earthen retort is to be suspended, by means of a crow's foot, which has three iron branches bent up. This crow's foot, *f*, hangs down from the top hole about half a foot; so that the bottom of the retort rests upon the meeting of the branches, and hangs immediately over the fuel. The opening, between the mouth of the furnace and the vessel, is filled up with broken crucibles, or potsherds, and these are covered over with ashes, which transmit the heat very slowly. This furnace then answers for distillations performed with the naked fire. Dr. Black had some of them provided with a hole in the side, from which the neck of the retort issued; and in this way he distilled the phosphorus of urine, which requires a very strong heat; but every opening on the side is to be avoided if possible.

For distillations with retorts performed in the sand-bath, there is an iron pot, fitted for the opening of the furnace *a*, and this is employed as a sand-pot, or capella vacua. In these distillations the vent becomes the door of the furnace, and it is more easily kept tight than when on the side. When it thus serves for the door, it may be covered with a lid of charcoal and clay.

This furnace answers very well too for the common still; part of which may be made to enter the opening and hang over the fire. In this case, likewise, the vent is the door of the furnace, by which fresh fuel is to be added. In ordinary distillations, it is never necessary to add fresh fuel; and even in the distillation of quicksilver, phosphorus of urine, and, indeed, during any process whatever, the furnace generally contains sufficient to finish the operation, so effectually is the heat preserved from dissipation, and the consumption of the fuel is so very slow.

This excellent furnace is too simple and chaste in its form to please the amateur chemist, or the common show lecturer on chemistry; and the necessity of using charcoal as fuel, tends to prevent its adoption among experimenters in England: hence it has never come into common use.

### *Knight's Furnace.*

Mr. Knight has made an alteration in the construction of Dr. Black's furnace, which, by adapting it for burning pit-coal,

has caused it to be more usually employed than the original invention of the Edinburgh professor.

Fig. 22, represents an outline of the former. It consists of an oval iron case, twenty-two inches high, twenty in its largest diameter, and fifteen in its shortest; lined with fire-brick, or fire-clay, for about three-fourths of its height from the top, which part forms the body of the furnace, while the under part, which is not lined, forms a very spacious ash-pit, *A*, is the body of the furnace, which is cylindrical, but a little oblique, that the flame of the fuel may heat the sand more equally than if it were a straight cylinder. The breadth of this cylinder is eight inches and a half, and its height fifteen. The grate, *c*, lies across the bottom.

This fire-place has the following openings above the grate; the highest is the large opening at the top, which, when a sand heat is employed, receives the sand-pot, *i*, and when this is not wanted, is covered by a thick iron plate, lined with clay. The next opening is the elbow of the chimney, *f*, which widens as soon as it takes a perpendicular direction, and, for the first few inches, forms a part of the iron case of the furnace, and is lined with clay, after which it is elongated by an iron tube fitted to it, and not represented in the figures. The degree of heat is regulated by varying the length of this iron tube. The third opening, *e*, serves to introduce fuel, and may be employed also to regulate the heat. The fourth opening consists of two small round holes, *g*, opposite to each other on the two sides of the furnace. Through them a porcelain, or iron tube, is occasionally introduced, when it is required to be heated to redness for any particular experiment. The last opening, *d*, is intended for introducing a muffle, and serves also, occasionally, to feed the fire. All these openings are furnished with thick brick stoppers, and iron plates which slide over them. There are two openings, *b b*, in the ash-pit, which serve to regulate the draught of air, and, of course, to vary the heat of the furnace.

As the full depth of the fire-room is something inconvenient, a second loose grate accompanies the furnace, and a stand for it, composed of two rings, kept apart by three pillars at equal distances. When this stand is placed on the ordinary grate, and the loose grate placed upon it, the latter is just below the level of the lower edge of the upper door.

This furnace is very generally employed in England as a polychrest furnace, both by amateurs and experimenters. Its great fault is its weight, which requires two persons to move it; it also ought to be raised on the base of a brick work, or a strong table, in order to be employed as a muffle furnace, as otherwise the operator must lie down on the floor to inspect the matters in the muffle.

### *Aikin's Blast Furnace.*

For the purpose of raising an intense heat in a short time, at an expense of very little fuel, Mr. Arthur Aikin contrived a convenient and cheap blast furnace, having taken up the idea of Dr. Lewis in his Philosophical Commerce of the Arts. This furnace is composed of three parts, all made out of the common thin black melting-pots, sold in London for the use of the working goldsmiths.

Fig. 23. The lower piece, *c*, is the bottom of one of these pots, cut off so low as only to leave a cavity of about an inch deep, and ground smooth above and below. The outside diameter, over the top, is five inches and a-half. The middle piece or fire-place, *a*, is a larger portion of a similar pot, with a cavity

about six inches deep, and measuring seven inches and a-half over the top, outside diameter, and perforated with six blast-holes at the bottom.

These two pots are all that are essentially necessary to the furnace for most operations; but when it is wished to heap up fuel above the top of a crucible contained, and especially to protect the eyes from the intolerable glare of the fire when in full height, an upper pot, *b*, is added, of the same dimensions as the middle one, and with a large opening in the side, cut to allow the exit of the smoke and flame. It has also an iron stem, with a wooden handle (an old chisel answers the purpose very well) for removing it occasionally.

The bellows, which are double, *d*, are firmly fixed, by a little contrivance which will take off and on, to a heavy stool, as represented in the plate; and their handle should be lengthened so as to make them work easier to the hand. To increase their force, on particular occasions, a plate of lead may be firmly tied on the wood of the upper flap. The nozzle is received into a hole in the pot, *c*, which conducts the blast into its cavity. Hence the air passes into the fire-place, *a*, through six holes of the size of a large gimblet, drilled at equal distances through the bottom of the pot, and all converging in an inward direction, so that, if prolonged, they would meet about the centre of the upper part of the fire.

No luting is necessary in using this furnace, so that it may be set up and taken down immediately. Coke, or common cinders, taken from the fire, when the coal ceases to blaze, sifted from the dust, and broken into very small pieces, forms the best fuel for higher heats. The fire may be kindled at first by a few lighted cinders, and a small quantity of wood-charcoal.

The heat which this little furnace will afford is so intense, that its power was at first discovered accidentally by the fusion of a thick piece of cast iron. The utmost heat procured by it was 167° of Wedgewood's pyrometer, when a Hessian crucible was actually sinking down into a state of porcelaneous fusion. A steady heat of 155° or 160° may be depended on, if the fire be properly managed, and the bellows worked with vigour.

This is a very convenient furnace for fusion when a person has not a proper blast furnace or forge.

### *French Evaporating Furnace.*

The portable furnace, called by the French, *fourneau evaporatoire*, is used for evaporating liquids, and the performance of other operations that require only a slight degree of heat.

Fig. 24, represents this evaporating furnace, or chafing dish, as we should call it; *a*, is the fire-room; *b*, the ash-room, to receive the ashes; *c*, the entrance into the fire-room, furnished with a stopper to rest on the slab; *d*, the entrance into the ash-room, having also a stopper; *e*, outlets by which the draught is maintained when the top of the furnace is closed, by a dish or kettle of larger diameter than the fire-room being placed upon it.

This furnace is always made of a single piece of stone-ware, and has generally, instead of a grate, a flat plate of the same ware, with round holes. The charcoal or other fuel is usually put in at the top, but sometimes on the side.

### *French Reverberatory Furnace.*

The portable furnace, called by the French *fourneau à réverbère* is used to expose substances to a greater degree of heat than can be produced in the last-mentioned furnace. The vessels used in it are almost always earthen retorts or crucibles.

Fig. 25, represents this common reverberatory furnace, known in Germany by the name of Beecher's furnace: *a*, is the fire-room; *b*, the ash-room; *c*, the

entrance into the fire-room, with a stopper resting upon a slab for that purpose; *d*, the entrance into the ash-room, with its stopper; *e*, the chamber separated from the fire-room by two iron bars, resting upon notches made in the upper part of the fire-room; *f*, the dome or cupola of the furnace, serving to reverberate the heat upon the retort when the furnace is used for distillation; *g*, a circular opening cut partly in the chamber of the furnace, and partly in the dome, to allow a passage for the neck of the retort; *h*, *n*, handles for conveniently moving the furnace. Those parts of the furnaces that are exposed to the greatest heat are sometimes bound with hoops or iron wires when the sides are not made sufficiently strong; *i*, the vent, upon which is occasionally, but rarely, placed a chimney of the same ware, three feet in height.

These two, or rather the last only, are almost the only furnaces used commonly in the laboratories of the French chemists. The chimney of the reverberatory is sometimes heightened by an iron pipe of six or nine feet in length, to augment the draught; and at other times the blast of a pair of double bellows is thrown into the fire, by a flexible pipe communicating with the bellows.

When uncoated glass retorts are used for distillation, the French chemists place on the iron bars that part of the fire-room and chamber, a sand-pot made of sheet iron, about an inch less in diameter than the internal cavity of the furnace, and having a notch in its side, which answers to the notch in the chamber. This sand-pot is placed as close as possible to that side of the furnace where this notch is situated, and the neck of the retort guarded from the heat by some clay stuffed between the pot and the furnace. The sides of the pot ought to be an inch higher than the arch of the retort, that it may be entirely covered with the sand, to defend it from the too great heat that might be reverberated upon it by the dome, which the French chemists are in the habit of using with the sand-pot. Earthen and cast iron sand-pots are thought by them to waste fuel, on account of their thickness.

For distilling with a large stone-ware body, it is placed on the two bars, and the dome being put on so that the neck of the body comes through the vent, *i*, and rises about two or three inches above it, a glass head is then luted to the body, and the space between the sides of the vent and the neck of the body stopped up with clay. In this case the notches, *g*, in the chamber and dome, serve as a vent. The French usually distil water, and vinegar by this apparatus. Instead of a body and glass head, a stone-ware bottle, stopped by a cork, and having a glass pipe passing through the cork, and properly bent so as to convey the vapour into a glass carboy, placed by the side of the furnace, is now more commonly used.

### *Macquer's Reverberatory Furnace.*

There is also another portable reverberatory furnace sold in Paris, and distinguished by the name of its introducer, the ce-

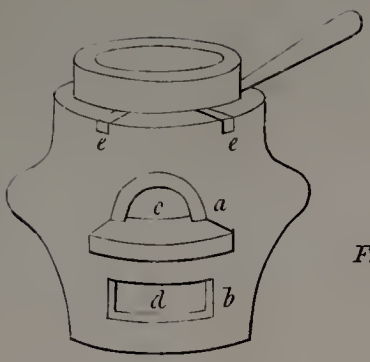



Fig. 24.

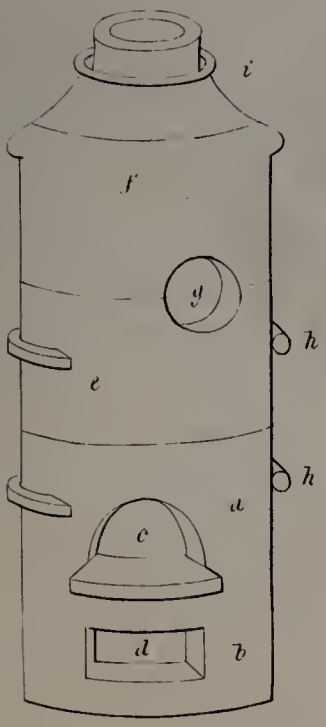



Fig. 25.

Fig. 26.

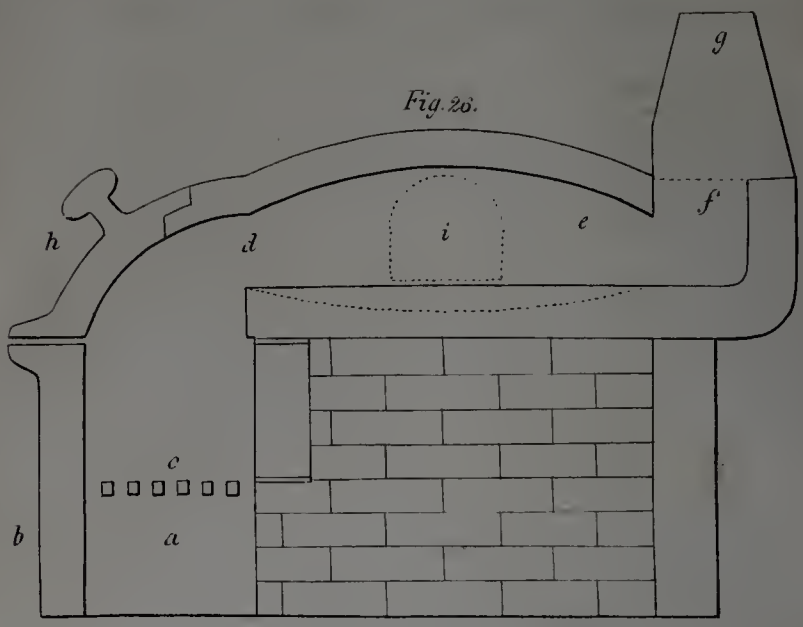



Fig. 27.

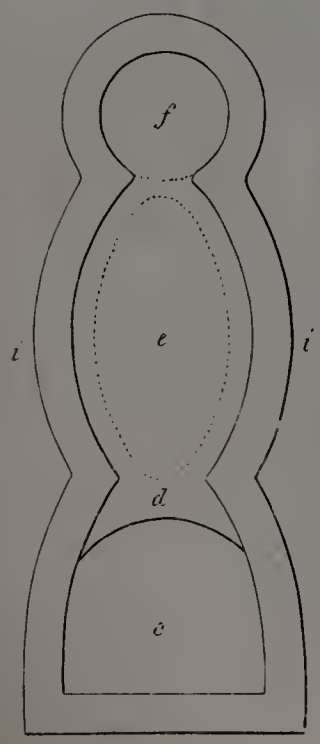
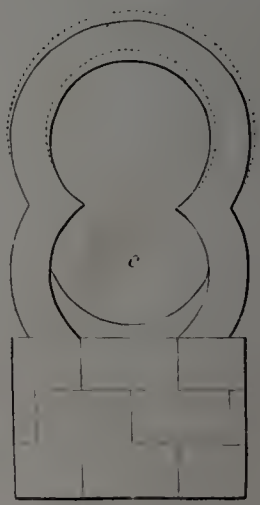



Fig. 23.



lebrated Macquer. In this furnace the chamber is on the side.

Fig. 26, represents a plan of this furnace on a scale of about an inch to a foot; Fig. 27, the longitudinal section; and Fig. 28, the transverse section of the chamber, in which the laboratory is made to rest on bricks set for that purpose;—*a*, is the ash-room, about nine inches deep from front to back, seven inches wide, and eight inches high; *b*, the entrance to the ash-room, closed with a stopper; *c*, the fire-room, with its grate; this room is of the same size as the ash-room, but the sides bulge out so as to enlarge its width to eight inches in the middle of its height; *d*, the throat, or passage, for the flame into the chamber; this is only five inches and a half wide at bottom, and arched at top; *e*, the chamber is of a long oval figure, about two feet in length, seven inches wide, and five high in the middle, and only three inches and a half wide, and as many high at the vent, *f*. The bottom plate of the chamber is full two inches thick, and its upper surface is hollowed out into a shallow basin. The flue, *g*, is circular, and five inches in diameter; over it is occasionally fitted an earthen chimney, two feet in height, lengthened, when necessary, by an iron pipe eight or nine feet long. The roof of the chamber is extended forward so as to cover the fire-room with half a cupola, in which is left a large feeding-door, *h*, closed with a stopper. The chamber has also two openings, *i*, *i*, one on each side, the largest for to introduce vessels or materials, and the smallest for the purpose of inspecting the progress of the operation or admitting air.

The many uses to which this furnace may be applied will be easily conceived by an experienced chemist, and by others they may be gathered from what has been said in p. 85, respecting the furnace with a chamber on its side.

### *Macquer's Lithogeognosic Furnace.*

Dr. Macquer has described another furnace in the Memoires de l'Academie des Sciences, for 1758, which is used in Paris when operations requiring intense heat are to be performed, under the name of the *fourneau lithogeognosique de M. Macquer*, it being copied from the wind furnace figured by Mr. Pott in his Lithogeognosie.

Fig. 29 and 30, show the front and side view of this furnace, as given by Baumé in his Chymie Experimentale et raisonnee. All the dimensions are not mentioned, and are here stated from their proportion to those parts whose admeasurements are known.

The fire-room, *a*, is entirely open at bottom, except a ledge of an inch and a half all round to support the grate, which is composed of seven bars placed with an edge uppermost, at half inch distances. The inside measure was eleven inches from side to side, and thirteen inches from front to back. There is no ash-room, as it merely stands upon a trivet, *d*, six inches high, so that the air has free access to the fire on all sides.

Three inches and a half above the surface of the grate, or five inches from the bottom line, is the opening into the fire-room, *b*, at which a muffle was usually introduced. This opening is semicircular, and described by a radius of one inch and a half, hence it is three inches wide at bottom. A stopper is fitted to this muffle door. It must be observed that the fire-room bulges on the sides so as to allow more space between the muffle and the side walls for the fire.

About six inches above the muffle door, the front and sides of the furnace slope, so that at the height of about a foot the fire-room is contracted to about eight inches square on the inside; but the back wall rises perpendicularly. This sloping part or dome, is made of a separate piece of stone-ware.

In the front of the dome, at eight inches above the upper edge of the muffle-door, is made an opening, *c*, to be used as a feeding-door; it has a stopper fitted to it, and is made as large as it well can be, to allow the more fuel to be supplied to the furnace at each time of opening it.

All the preceding parts are made of an apyrous clay, brought from Vaugirard, and are two inches thick.

The vent at the top of the dome is nearly eight inches in diameter, and has a stone-ware chimney, *e*, adapted to it, which is two feet high, six inches diameter internally, and an inch thick. This chimney is usually lengthened by an iron pipe of the same diameter, and twelve feet high.

The muffles used in this furnace are eight or nine inches long, semicircular, with a radius of an inch and a half, close on all sides except the front, and from one line and a half to two lines thick; ten small crucibles may be placed in them.

In the Memoires for 1767, Dr. Macquer relates some experiments made with a furnace of this kind, but two inches larger every way, which are very interesting, on account of their showing the differences of effect produced by altering the length and diameter of the chimney.

When this larger furnace, whose fire-room was, of course, about fifteen inches from front to back, and thirteen wide, had a chimney adapted to it, of six inches diameter, and eight feet in length, the furnace consumed a voie, or about 130 pounds of charcoal in an hour, roared so that the noise resembled that of a coach rattling over a bridge, and all the glasses and other things in the laboratory were strongly shaken.

This fire being continued for three hours, the following substances, which had been exposed to the fire, were found to be thus altered:—1. A Norwegian stone, resembling Briançon, or French chalk, was merely hardened externally. 2. Unwashed white clay, and the same washed, were only hardened, and showed no signs of melting. 3. A hard crystalline substance from Alençon, was entirely melted into a white milky glass. 4 Gypsum was melted. 5. Calx of tin, prepared by nitric acid, was changed to a red colour, and had begun to melt. These substances were chosen for experiment, because Mr. Pott had found them to resist all his efforts to melt them.

When the chimney was lengthened to fourteen feet, the effects were inferior, although the firing was continued for seven hours.

When sixteen feet of chimney, eight inches in diameter, were used, and the fire was continued for three hours and a half, the effects were superior to those of the last experiments.

The effects of the fire were fully equal to those obtained by Mr. Darcet, in the Count de Lauraguais' porcelain furnace, heated by wood, after several days' firing; although much heat was lost in using this portable furnace, as the chimney was red hot for six feet in height.

M. Guyton de Morveau relates, in Annales de Chimie, tom.

Fig 29

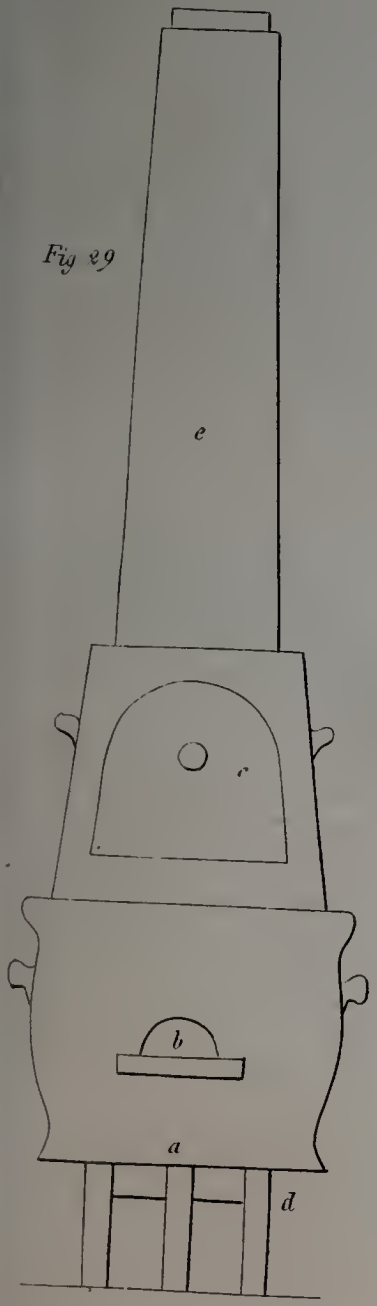
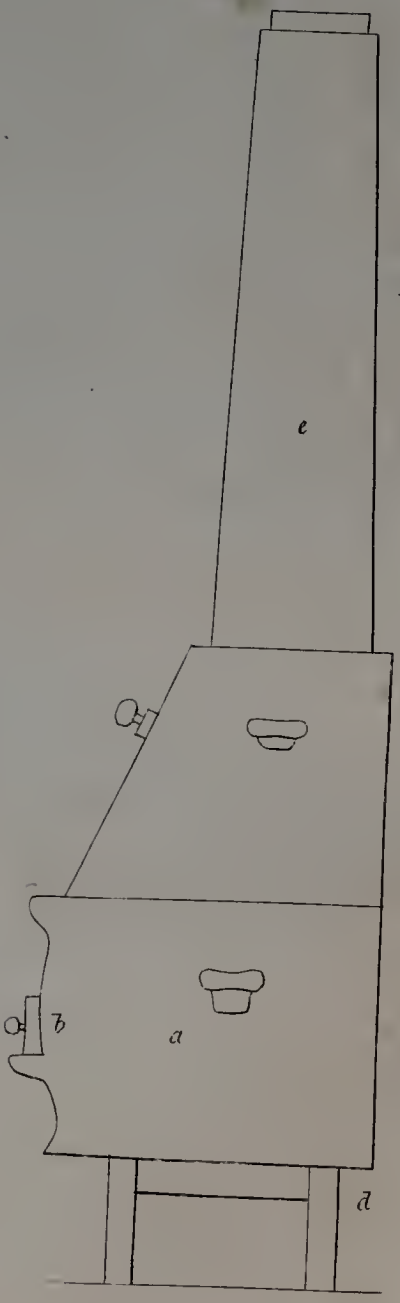
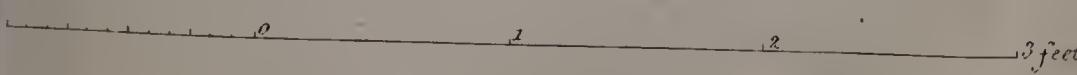



Fig. 30.



29, some experiments he made with the identical furnace of Macquer, but whether his first or second, does not appear, although it was probably the last. De Morveau's object was to increase the draught upon Venturi's principles.

In consequence, he made use of a chimney eight feet long; the lower part, to the height of three feet and a half, was cylindrical, and two inches and a quarter in diameter, the upper part being four feet and a half high, widened gradually to the top, where it was five inches and a third in diameter.

After a firing of an hour and a half, Wedgwood's pyrometer marked 154 degrees, but it had evidently retrograded, as its specific gravity was only 2.255. A platina dish exposed to this heat, was much more affected than it had been in a forge with three blast pipes, where the pyrometer once marked 174 degrees and a half, as the dish had begun to melt on the edge, which was not the case in the forge, where some parts only of it swelled out like a cauliflower.

M. Guyton thinks that dishes of platina placed on a cheese of apyrous clay, and covered with an inverted crucible, are the most advantageous vessels that can be used in experiments on the fusion of earths and stones.

### *Caléfacteur Lemare, or French Portable Kitchen.*

There is another portable furnace lately used in France, as a very economical boiler, under the title of the Caléfacteur Lemare, from the name of its introducer.

Fig. 31, represents a section of this M. Lemare's furnace and boiler; *a*, *b*, *c*, *d*, is a double cylindrical vessel having a hole, *h*, in its bottom, capable of being shut by a slider, *c*, *h*. There are only three openings into the space between the two vessels; one near the top, by which water is poured into this space, and is then stopped with a cork, *k;* the second is also at the top, and to this is soldered a small pipe, *l m*, directed downwards to carry off the steam; the third is a cock, *b*, at the bottom, to draw off the heated water upon occasion.

A shallow iron dish, *g*, nearly fitting the internal cavity of this cylinder, and pierced with several holes, is supported upon three legs, at about half an inch from the bottom: this dish is to hold the charcoal used as fuel.

The proper boiler, *i*, fits into the mouth of the outer vessel, or furnace, and descends about two-thirds of its depth into it.

A second boiler, *p*, fits in like manner into the mouth of the large boiler, *i*, and has a cover which fits very close.

Both the outer vessel, and the large boiler, *i*, have falling handles, by which they may be lifted up.

Lastly, a blanket, a piece of baize, or an Angola shawl, *r*, *s*, *t*, *u*, is used to cover the whole when in use."

When this furnace is used for preparing soup, or dressing vegetables, which is its most general use, water is first poured into the outer double vessel, to fill the space between them. The meat is then put into the large boiler, *i*, generally with a

quart of water to each pound. Some charcoal, a part of which is lighted, is then put upon the iron dish, *g*, and the large boiler is put into the furnace, so that three little projections near its rim do not fit into their correspondent openings in the double vessel; by which means a passage is left for the air, which has entered at the hole, *h*, in the bottom of the furnace, and acted upon the charcoal, to escape. The small boiler is fitted into the mouth of the other, and in about thirty-six or forty minutes, the water in the double vessel begins to emit steam at the end, *m*, of the steam-pipe, *l m*, which shows that the water in the large boiler has attained nearly a boiling heat.

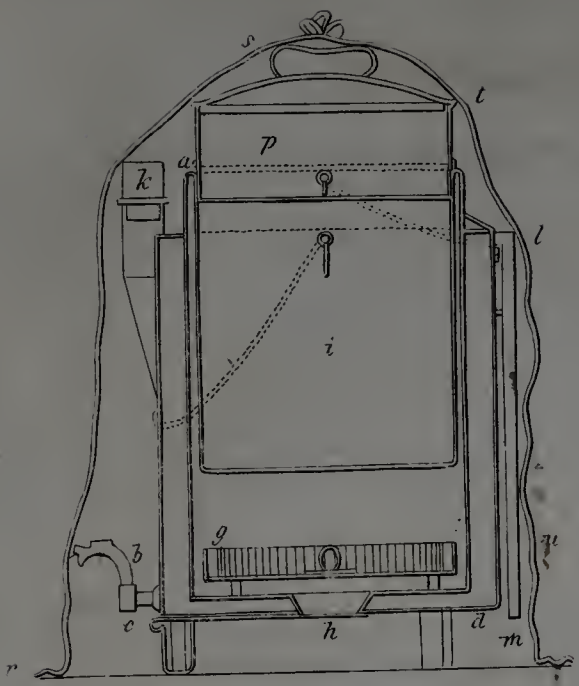
The small boiler is then taken off, the broth scummed, the vegetables and salt put in, and the small boiler being replaced, the large boiler is turned so that the projections on its rim fit into their places, and the passage of any air through the fire stopped; the slider is also shut, and the whole covered with the blanket, to retain the heat. In about six hours the soup is considered as being sufficiently cooked; there is also a quantity of hot water in the double vessel and the small boiler, to wash the dishes, or for any other purposes.

That excellent chemist, M. Thenard, is of opinion it would be better to have some very small holes in the slider, and that the large boiler should not fit accurately into the double vessel, in order to allow a very slow combustion of the charcoal to continue during the whole process.

The economy in using the caléfacteur is evident, as, on an average, ten avoirdupois ounces of charcoal, is sufficient for cooking six pounds of meat into nine pints of soup.

Thirteen quarts and a-half of water, at about 71 degrees of Fahrenheit, being put into the double vessel and small boiler, and fifteen quarts and a-half in the large boiler, and two pounds of charcoal in the iron dish, was left for three hours and three-quarters; the fire was then stifled by shutting the slider, and on being taken out, it was found that about three ounces were left unconsumed. Six quarts and about a third had steamed away, so that reckoning the heat communicated to the furnace and boilers, weighing altogether nearly twelve pounds, the heat had produced nine-tenths of its maximum theoretical effect.

The principle adopted in this furnace, of having the fire within the boiler, had been already used by Mr. Trevethick, in the boilers for his high-pressure steam-engines. It is also, as we learn from Kæmpfer, in universal use in Japan for the tea-canteens, in which all persons in easy circumstances carry hot water with them when on a journey, or party of pleasure, that they may refresh themselves at any time with a dish of tea, without going into any house of entertainment.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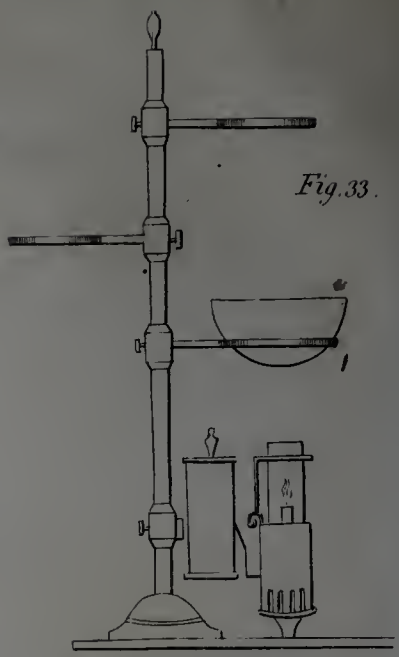
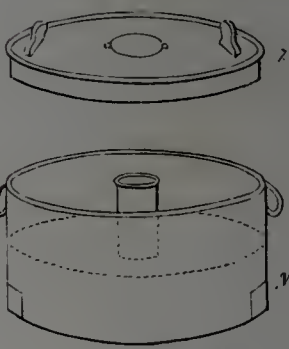


Fig. 33.
l

Fig. 32.
x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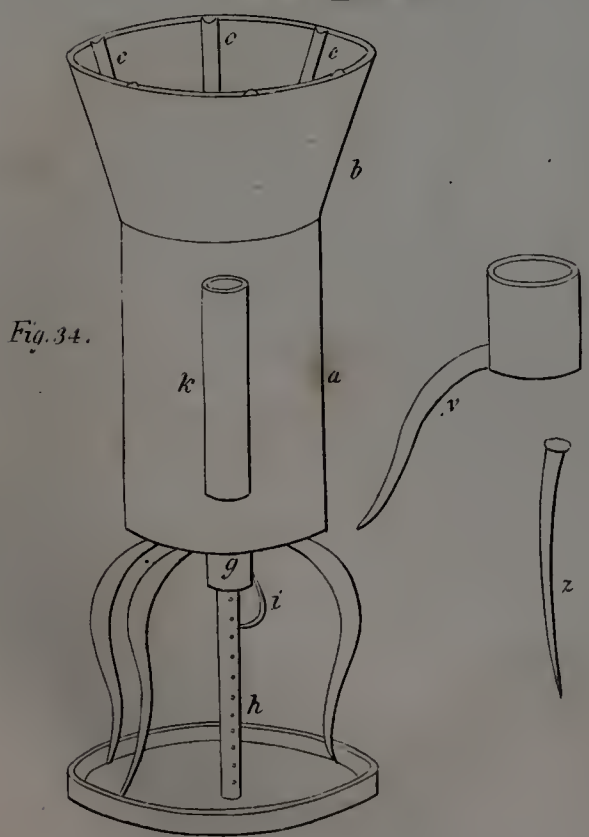
c
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Fig. 34.
k
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g
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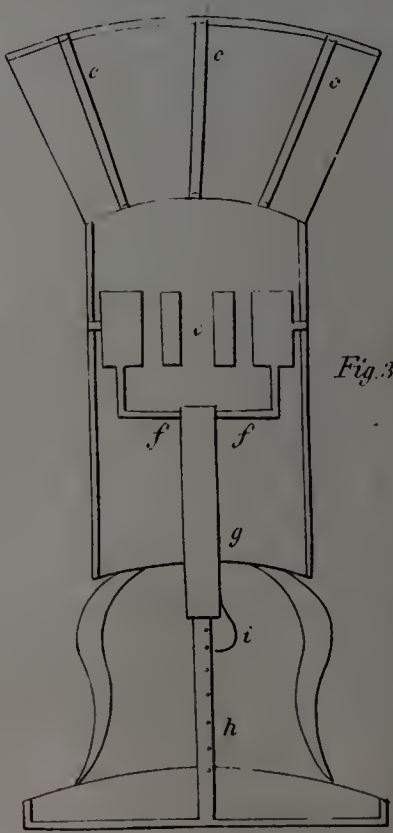
c
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c
Fig. 35.
f
f
g
i
h

Fig. 32, represents some additional apparatus to the caléfacteur Lemare, to adopt it for the preparation of roast meat, that is to say, what the Parisians understand by that name.

*W*, is an iron support, with two handles, to let down into the caléfacteur instead of the boiler, *i*, to support the shallow iron frying-pan without a handle, *x*, about three inches above the charcoal on the grate, *g*.

The upper boiler, *p*, is replaced by another, *y*, of a different form, a couple of notches in its sides allows it to pass the handles, *w*, of the support of the roasting-pan, above these notches, it has a bottom and a vent-pipe through its middle for the vapour of the meat. This boiler, like the two others, may be divided into two or three partitions, in order to cook several different dishes at the same time. It has a cover, *a*, which fits very close, and has a hole in the middle, answering to the vent-pipe, which is closed at pleasure by a sliding plate.

It is asserted that this caléfacteur, or portable kitchen, will reverberate the heat sufficiently to roast the pieces of meat, or poultry, placed on the iron pan, *x;* and when the meat is done enough, by closing the register, *c h*, at the bottom of the caléfacteur, and the vent-pipe in the boiler, *y*, the charcoal is extinguished, and the roast meat may be kept in a proper state for serving up an hour or two afterwards!

The materials of which this furnace and its boilers are made are not stated in the book from which this account is extracted; the prices, as quoted for Paris, seem rather dear, a caléfacteur for one pound of meat, 15*s.*; for two pounds, 18*s.*; for three pounds, 22*s.*; for four pounds, 27*s.*; and for five pounds of meat, 32*s.*

## LAMP FURNACES.

For chemical experiments upon a small scale the spirit lamp is by far the most convenient kind of lamp, as the flame of spirit of wine does not blacken, or in any degree soil the vessel to which it is applied; and as the degrees of heat may be regulated merely by raising the lamp higher up, or by placing it lower down, any short small glass bottle may be made to answer for a spirit lamp; but, in order to prevent waste of the spirit by evaporation, the spirit lamp requires to have a glass cap fitted to it by grinding, so as to enclose the wick air-tight.

An Argand's lamp sliding on a pillar, which has also two or three rings sliding on it, represented at Fig. 33, is very frequently employed at present for evaporations, and similar operations which do not require any great heat.

Both these lamps have, however, the inconvenience of wasting the far greater part of the heat from the free access of the cold air on every side; and the heat is also confined to a single point of the vessel, so that only liquids, or at least solids, fusible by the heat to which they are exposed over the lamp, can be properly operated upon with this apparatus.

### *Dr. Percival's Lamp Furnace.*

The first objection to lamp furnaces has been removed by

Dr. Percival, but the second is not avoided in his lamp furnace.

Fig. 34, represents Dr. Percival's chamber lamp furnace, of which a section is shown in Fig. 35. It consists of a cylindrical body, *a*, about four inches in diameter, and nine and a-half high, surmounted by a laboratory, or space for containing vessels, which is a hollow truncated cone, *b*, six inches and a-half wide at top, and four at bottom. Its conical shape adapts it to vessels of different sizes. To the inside of the laboratory are riveted six tubes, *c*, one-quarter of an inch diameter, in which the vessel rests, so that space sufficient for the passage of heated air is interposed between it and the inside of the laboratory. Into three of these tubes, iron spikes, *z*, previously fitted to them, are occasionally introduced: their converging extremities form a support for vessels, the bottoms of which are less than four inches in diameter.

In one of these tubes, *c*, whilst the lamp is burning, is placed the small pipe, *y*, which, communicating with the reservoir, supplies oil gradually to the lamp, through an aperture contrived for that purpose. The lamp, which is contained in the body of the furnace, is made according to Argand's construction, with an oil cistern, which is a hollow cylinder. The diameter of the wick-holder, in the clear, is one inch and a half; the diameter of the interior circular air aperture, *e*, Fig. 58, is one inch and a quarter.

The lamp is supported by two cross stays, *f*, which are fixed to the top of the tube, *g*. This tube rises and falls on the stem, *h*, and is fixed at different heights by means of the spring-catch, *i*, which is fastened to the tube, and fits into holes made in the stem. The tube in rising and falling carries with it the lamp, which by this means may be supported at different distances from the vessels in the laboratory. The furnace itself answers the purpose of a chimney to the lamp.

In the body of the furnace is an opening, *k*, Fig. 34, for trimming the lamp: this may be closed by a slide. When it is closed, the heat of the lamp is considerably increased, for reasons too obvious to be insisted upon. The bottom of the lamp, to make it more steady, is loaded with lead.

To determine whether the heat produced would be greater, if the external air-aperture of the wick-holder were diminished, a stopper was made, half an inch in diameter, which, fitting into the central aperture with a spring, left a circular opening three-eighths of an inch wide for the passage of air.

It was then observed with a thermometer and stop watch, at what rate quicksilver, contained in a glass solution bottle which was placed in the laboratory, acquired temperature; first, when the stopper was not employed, and afterwards when it was. The bottom of the vessel was one inch and seven-eighths distant from the edge of the wick-holder.

The result of these observations is contained in the following table. At the beginning of the observation, the thermometer placed in the quicksilver stood at 113.5.

*Without Stopper.*

| Minutes of observation. | Temperatures. | Increments of temperature in a minute. |
|---|---|---|
| 1 | 143.5 | 30 |
| 2 | 174 | 30.5 |
| 3 | 203 | 29 |
| 4 | 231 | 28 |
| 5 | 256 | 25 |

In five minutes, 142 degrees .5.

*The stopper put in.*

| | | |
|---|---|---|
| 6 | 292 | 36 |

The increment of temperature in this sixth minute was diminished by lowering the slide for the admission of the stopper.

| | | |
|---|---|---|
| 7 | 335 | 63 |
| 8 | 409·5 | 54.5 |
| 9 | 458 | 48.5 |
| 10 | 500 | 42 |

In five minutes, 244 degrees.

It is obvious that the effect of the stopper, in increasing the heat, must have been considerable; as, from the former part, it appears that as the temperature of quicksilver increases, the increments of its temperature in a given time, circumstances remaining the same, diminish; yet the sum of the increments, in the last five minutes, considerably exceeds the sum of the increments in the first.

The effect of diminishing still farther the internal air-aperture of the wick-holder was then tried: a ring being adapted to the stopper, it increased its diameter to seven-eighths of an inch, and consequently diminished the width of the circular opening for air to three-sixteenths of an inch.

The following table will show the effect of this alteration. In this experiment the lamp burnt less briskly than in the former. The temperature of the quicksilver at the beginning of observation was 113.5.

*Without Stopper.*

| Minutes of observation. | Temperatures. | Increments of temperature in a minute. |
|---|---|---|
| 1 | 135 | 21.5 |
| 2 | 157.5 | 22.5 |
| 3 | 177 | 19.5 |
| 4 | 196 | 19 |
| 5 | 213 | 17 |

In five minutes, 99 degrees .5

*The enlarged Stopper put in.*

| | | |
|---|---|---|
| 6 | 247 | 34 |
| 7 | 329 | 82 |
| 8 | 402.5 | 73.5 |
| 9 | 468 | 65.5 |
| 10 | 524 | 56 |

In five minutes, 311 degrees.

As the proportion of 311 to 99.5 is much greater than that of 244 to 142.5, the enlarged stopper appeared to have considerable advantage in increasing the heat.

The comparative effect of the two stoppers was determined by another trial, and it is shown in the following table:

*Lamp with enlarged Stopper.*

Temperature of quicksilver 125.

| Minutes of observation. | Temperatures. | Increments of temperature in a minute. |
|---|---|---|
| 1 | 175 | 50 |
| 2 | 228 | 53 |
| 3 | 274 | 46 |

In three minutes, 149 degrees.

*Lamp with small Stopper.*

Temperature of quicksilver 125.

| | | |
|---|---|---|
| 1 | 170 | 45 |
| 2 | 214 | 44 |
| 3 | 254 | 40 |

In three minutes, 129 degrees.

Thus it appears that in lamps made on this construction, the internal aperture for air may be considerably diminished with advantage. What is the most advantageous opening has not been determined; but it is probable, that it would not bear to be diminished much more than in the experiment last recited.

## *Baumé's Lamp Sand-bath.*

M. Baumé's lamp-furnaces are superior to any of the preceding, for the purpose of distillation by a gentle heat, by a bath of water, or sand. He justly observes, that as lamp-furnaces require less attention than those in which wood, or other fuel is burned, they suit the convenience, and meet the approbation of many persons.

M. Baumé constructs his lamp-furnaces of thin sheet-iron, and uses common olive-oil, or Galipoli-oil, as it is also called; but any other oil, which does not give out much smoke in burning, may be also used. Four, five, or six wicks, either of cotton, amianthus, or gold wire, may be put into the lamp, and only so many of them lighted as may be sufficient. The wicks are easily arranged by scissors and spring forceps.

Fig. 36, represents M. Baumé's lamp-furnaee, as fitted for a sand-bath; *a*, is the body of the furnaee, made as above stated, of thin sheet-iron, and having towards the bottom three or four openings, to admit the air. It has also an arehed opening at *b*, to allow the branch of the lamp whieh contains the wieks to enter the body of the furnaee; *c d*, is the lamp itself; *c*, being a glass reservoir for oil, such as is usually sold by the bird-eage makers for bird-fountains in aviaries, but furnished with a tin plate valve at its mouth, to prevent the oil from running out, while it is being taken away, or put into the bottom, *d*, of the lamp; though this may be dispensed with if the party does not mind greasing his fingers, and spilling a little of the oil. The bottom, *d*, of the lamp, is made of tin-plate, and has a braneh, *b*, of sufficient length to enter the body of the furnace, and allow the wicks, whieh are disposed in two rows at the end of the braneh, to be placed in the eentre of the furnace.

At the top of the body, a sand-pot, *e*, of thin plate-iron, fits in and enters about two or three inehes deep, a small flange, or pins are fastened round this pot, to prevent it from entering deeper into the pot. In this pot is usually worked a retort, *f*; to which is luted a reeeiver, *g*.

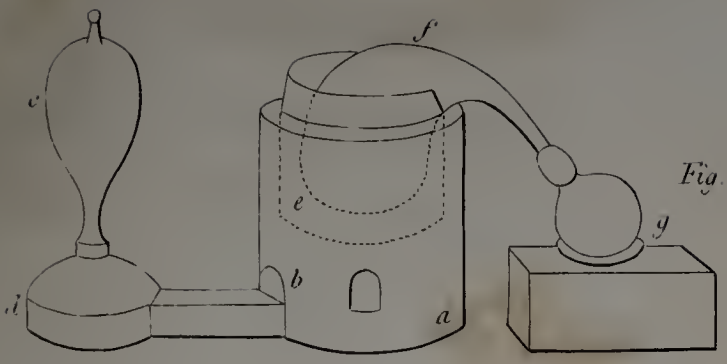



Fig. 36

Fig. 37.

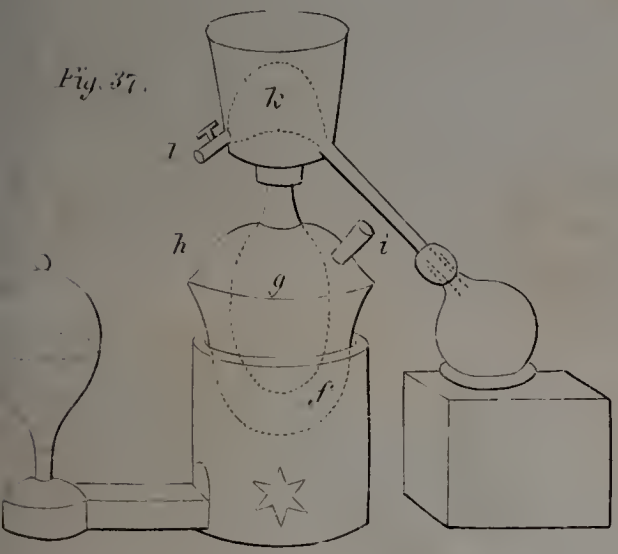
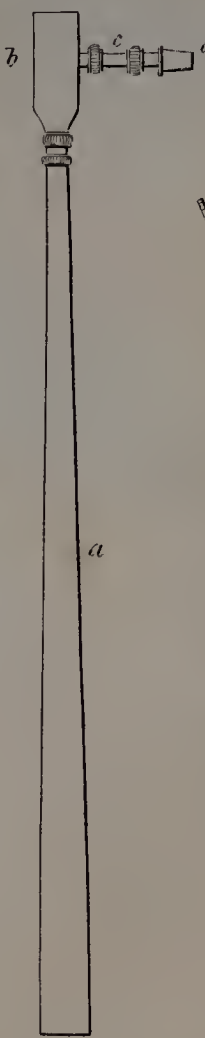



Fig. 39



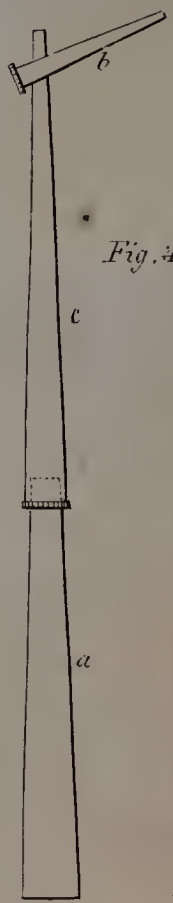
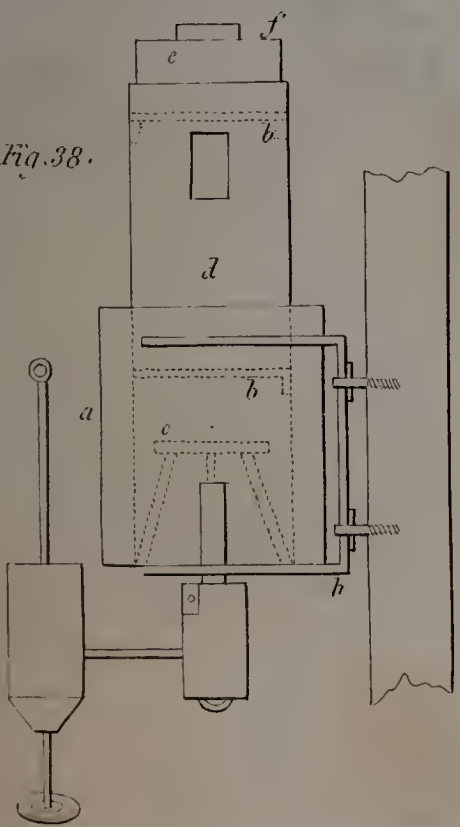




Fig. 40.

Fig. 38.



In the lamp furnace thus fitted, many spiritous liquors may be distilled, several essential oils rectified, and many other operations performed.

### *Baumé's Lamp Water-bath.*

The apparatus for adapting M. Baumé's lamp-furnace for distillation by the water-bath, is rather more complicated.

Fig. 37, exhibits the lamp water-bath of Baumé. The body of the furnace and the lamp, remains as before, but in place of the sheet-iron sand-pot, a tin-plate vessel, *f*, is fitted into the top of the body of the furnace, to hold the water forming the bath, in which is plunged a glass or pewter body, *g*. A cover, *h*, that fits very close, is then put over the bath, which has a hole just big enough to allow a passage to the neck of the body; and this cover has also a small pipe, *i*, to let the steam escape, and by which fresh water may be added as may be required.

A glass head, *k*, is placed on the body, and generally luted with slips of paper, rubbed over with paste or starch. A refrigeratory, *k*, is often placed upon this head, and for the sake of being the better enabled to fit it to the surface of the head, this refrigeratory is made of milled lead, and has a small notch on one of its sides, to suit the enlargement of the head where the nose is placed. The joining between this refrigeratory and the head is secured, first by a small roll of fat lute, and, secondly, by a strip of linen, upon which a lute of cheese and quick-lime has been spread. A small cock, *l*, is soldered to the refrigeratory, that the water, when heated, may be drawn off.

The fine spiritous perfumes may be distilled in this apparatus to great advantage.

### *Baup's Lamp Reverberatory Furnace.*

In experimental researches, it is frequently necessary to dry the products completely, by the passage of heated air over them in a kind of reverberatory, for which purpose D'Arcet's lamp furnace is generally used in France.

M. D'Arcet's stove is described, in Thenard's Traité de Chimié, as consisting of a four-sided chest, made of very dry wood; but the temperature could never be raised above the heat of boiling water, even after several hours. By the improvement of M. Baup, a chemist of Vevay, he has been able to dry substances by a heat of 150 degrees cent, equal to 302 degrees Fahrenheit, or even a little more.

M. Baup's stove, represented in Fig. 38, is cylindrical, of three pieces, each piece being composed of two pieces of pasteboard, glued together, so that where they join the two sheets of the first and second cylinders, may differ in height, and that the projecting edges may fit into corresponding recesses in the lower edges of the second and third cylinders; by which means the pieces are kept steady one upon the other.

The lower, or first cylinder, *a*, of eight inches diameter, and twelve high, is closed at bottom by a circular piece of pasteboard, having a hole in the middle to introduce the glass chimney of an Argand lamp. It is also surrounded, at the distance of about two inches, with another cylinder, made of a single pasteboard. The space between the two cylinders is filled with carded cotton, or wool, and covered at top with a circular band of pasteboard. Near the top of

this cylinder, a circle, or ring of pasteboard, is fixed, serving to support iron wire gratings, *b*, on which the substances to be dried are placed.

There is also a circular plate of iron, *c*, pierced with holes all round its border, and supported on three wires, placed in the lower part, which serves, like the mushroom in M. D'Arcet's stove, to prevent the heat of the lamp from acting on one point only, and to distribute it equally.

The first piece is surmounted by a second, *d*, about nine inches high, with a plate of glass fixed on one side. The top of this piece is also surrounded with a pasteboard ring, *b*, to support a wire grating.

The third piece, *e*, is only about three inches high, and is closed at top with a circular piece of pasteboard, having a circular hole in the middle, rather larger than the hole at bottom, to admit the chimney of the Argand's lamp: over this hole a plate of glass, *f*, is occasionally laid, to close the opening, more or less.

The stove itself is supported either by an iron frame, *h*, which may be secured against a wall, or by the rings of a common pillar-stand, of a large size, having its foot well loaded.

Before the outer cylinder was added as an envelope to the first cylinder, the heat on the lower grating could not be raised to more than 120 degrees cent, or 248 degrees Fahrenheit. When the outer cylinder was added, but left empty, the heat rose to 130 degrees, or 266 degrees Fahrenheit. The space between the cylinders being filled with charcoal, it took a longer time to arrive at 130 degrees, and the heat never went beyond it. But on filling the space between the inner and outer cylinder with wool, carded cotton, or feathers, the heat increased to 150 degrees, or 302 degrees Fahrenheit, and even to 160 degrees, or 320 degrees Fahrenheit, but less rapidly.

To procure the utmost effect of this stove, it is necessary to stop the space between the chimney of the lamp and the hole in the bottom of the stove with cotton or wool, and to close the opening at the top, as much as the necessary draught to prevent the lamp from smoking will allow.

This furnace may be considered as a lamp reverberatory furnace, or a miniature hot-air stove.

## BLOW-PIPES.

The workers in gold and silver, and some other tradesmen, use a plain blow-pipe to melt the solders they employ to join different pieces of metal, but this instrument is so fatiguing to the lips and cheeks, when it is used for any continued blast, that the chemical mineralogists have attempted to make several improvements in its construction.

### *Gahn's Blow-pipe.*

Berzelius, in a late excellent treatise on the use of the blow-pipe in chemistry and mineralogy, gives the preference to Gahn's construction, with an additional bent beak, for a laboratory blow-pipe, and to Wollaston's for a pocket instrument.

Gahn's blow-pipe is represented in Fig. 39. It consists of four pieces, *a*, *b*, *c*, *d*, which fit into one another very tightly. The cylindrical form of the chamber, *b*, destined to condense and collect the moisture of the breath, is far more advantageous than the forms given to this part by other chemists. By long wear, the end of the tube, *a*, will, indeed, enter farther into the chamber than at first, but this is no inconvenience; in other blow-pipes the chamber is liable to drop off the tube, or the joints to let the air escape.

Berzelius has found it convenient to add to Gahn's original construction, the bent beak, *e*, which, when inserted in the hole of the chamber, in the place of the original beak, *d*, can have whatever direction given it is necessary for glass-blowing.

The length of the tube ought to be such, that the substance on which the flame of the lamp is directed, may be at that distance from the eye of the operator, at which his vision is the most perfect.

Blow-pipes ought to be made of silver, or tin plate, with the beaks only of brass. When the tube and chamber are made of brass, they give out an ill smell, and have a coppery taste. Some endeavour to remedy these defects by an ivory mouth-piece, but still the smell remains uncorrected, and after some time the hands acquire a smell of verdigris, unless extraordinary care is taken of cleaning the instrument almost every time it is used. The joining of the tube with the chamber, if made of tin-plate, may be fully secured by wrapping a bit of paper round the tube.

The tips added to the beak are a great improvement; Berzelius has them made of platinum, for as they soon become filled with soot, and require the hole to be continually cleaned, he finds this the most advantageous metal, as he can heat them red with the blow-pipe, upon a piece of charcoal, and thus burn out the soot in an instant. It might be thought that silver tips would serve the purpose; but silver, when heated red, takes a crystalline texture on cooling, and becomes quite brittle.

### *Dr. Wollaston's Blow-pipe.*

Dr. Wollaston has reduced the size of the blow-pipe to the very smallest, and by an ingenious contrivance, has brought it into the compass of a common pencil case, so that it may be carried in a pocket-book, along with a slip of platinum foil, and and a little borax, and thus enable the operator to make an instant examination of any suspected pharmaceutical preparation, or ill-assorted mineral in a collection.

Fig. 40, represents this blow-pipe of Dr. Wollaston, which is composed of three pieces, two of which, *a*, *c*, are of metal, the third, *b*, of wood tipped with metal, in order to afford a sufficient obstacle to the communication of heat to the first piece, *a*. The three pieces slide into one another, and are thus reducible to the smallest possible compass.

Berzelius observes that this blow-pipe is not adapted for those cases on which it is intended to examine the properties of substances with great care, because the pieces do not fit sufficiently well to prevent the loss of some of the breath; there is also no

reservoir for the moisture, and as the beak is placed at an obtuse angle on the stem, the direction given to the flame is such, that the body operated upon is in some measure hidden by the flame.

The best general support for bodies to be exposed to the blow-pipe is charcoal of soft wood, made by stifling, and sawed into small bars; charcoal made by distillation conducts heat so much better that it is totally unfit to be used as a support.

The blow-pipe, when skilfully handled, Mr. Children observes, is the most convenient chemical instrument for mineralogical researches, on a small scale, that has hitherto been invented. By its means we are enabled, in a few minutes, to determine the principal ingredients in any mineral submitted to our examination, even though it be composed of several elements. By merely directing the flame of a small lamp, in which olive oil is burned, on a fragment about the size of a large mustard seed, supported on a piece of charcoal, or a hook of fine platinum wire; most of the volatile substances, as sulphur, arsenic, zinc, cadmium, antimony, bismuth, and tellurium, may be detected.

Barytes will be known by the greenish yellow; and strontites by the crimson colour it imparts to the flame.

By employing only three flues, carbonate of soda, borax, and the triple phosphate of soda and ammonia, formerly called microcosmic salt, with the occasional use of the nitrate of cobalt, we can readily ascertain the presence of silica, alumina, magnesia, and almost all the fixed metallic oxides; and by the farther examination of the fused globule, especially that with carbonate of soda, by dissolving it in a drop of muriatic or nitric acid, on a slip of glass, and applying the proper tests, unequivocal evidence may be obtained of the presence of any of the other earths or oxides of which the substance is composed, and even a tolerable estimate may frequently be formed of their respective proportions.

By substituting nitrate of barytes as the flux, and using a slip of platinum foil for the support, instead of the wire, the presence of either of the alkalies may, by the well known processes, be detected with equal ease and certainty, on the same minute scale of operation.

An advantage peculiar to this microscopic chemistry is the very small quantity of matter that is sufficient for examination, which may generally be detached from rare and costly specimens without injury; whereas, for operations on a larger scale, it is necessary, wholly or in great measure, to destroy them.

When the exact proportions of the ingredients of a mineral are required, recourse must necessarily be had to more elaborate processes. But, even then, previous examination by the blow-pipe is of essential service, since, by indicating the different substances present, it enables us to determine the most advantageous method to be adopted in the subsequent operations.

To acquire the proper command of the instrument, which requires considerable practice, the best method is to keep as large a button as possible of tin melted upon the charcoal, and to bring it to a white heat, still retaining its metallic appearance. Tin is so easily calcined that, as soon as the propelled flame acquires an oxidizing quality, an infusible crust of oxide will cover the button. To prevent this oxidizement the beak of the blow-pipe must be very fine and not pushed too far into the flame of the lamp; which also must not have a long wick, as that would produce a smoking flame, soil the button, and diminish the heat.

## FIRE-PLACES OR FURNACES FOR HEATING ROOMS.

There is another class of furnaces, not usually considered in books on chemistry, but which is, nevertheless, of great importance, namely, those which are used to heat the apartments in our dwelling-houses, our work-shops, and our repositories for foreign plants.

### *Rumford Stoves.*

The great fault of all the open fire-places for burning wood or coals, now in common use, as Count Rumford very justly observes, is, that they are much too large; or, rather, it is the throat of the chimney, or the lower part of its open canal, in the neighbourhood of the mantel, and immediately over the fire, which is too large. This opening has hitherto been left larger than otherwise it probably would have been made, in order to give a passage to the chimney-sweeper.

As the immoderate size of the throats of chimneys is the great fault of their construction, it is this fault which ought always to be first attended to in every attempt which is made to improve them.

As the smoke and vapour which ascend from burning fuel, rise in consequence of their being rarefied by heat, and made lighter than the air of the surrounding atmosphere; it is clear the nearer the throat of a chimney is to the fire, the stronger will be what is called its draught, and the less danger there will be of its smoking. But, on the other hand, when the draught of a chimney is very strong, and particularly when this strong draught is occasioned by the throat of the chimney being very near the fire, it may so happen that the draught of air into the fire may become so strong, as to cause the fuel to be consumed too rapidly.

Nothing can be more perfectly void of common sense, and wasteful and slovenly at the same time, than the manner in which chimney-fires, and particularly where coals are burned, are commonly managed. Servants throw on a load of coals at once, through which the flame is hours in making its way, and frequently it is not without much trouble that the fire is prevented from going quite out. During this time no heat is communicated to the room; and what is still worse, the throat of the chimney being occupied merely by a heavy dense vapour, not possessed of any considerable degree of heat, it happens not unfrequently, that the current of warm air from the room which presses into the chimney crossing upon the current of heavy smoke which rises slowly from the fire, obstructs it in its ascent, and beats it back into the room. Hence it is that chim-

neys so often smoke when too large a quantity of fresh coals is put upon the fire. So many coals should never be put upon the fire at once, as to prevent the free passage of the flame between them. When proper attention is paid to the quantity of coals put on, there will be very little use for the poker; and this circumstance will contribute very much to cleanliness, and to the preservation of furniture.

It will be found, upon examination, that the best form for the vertical sides of the chamber of a fire-place, or the covings, as they are called, is that of an upright plane, making an angle with the plane of the back of the fire-place, of about 135 degrees. According to the present construction of chimneys, this angle is ninety degrees, or forms a right angle; but as in this case the two sides or covings, of the fire-place, *a*, *b*, *c*, *d*, Fig. 41, are parallel to each other, it is evident that they are very ill contrived for throwing into the room, by reflection, the rays from the fire which fall on them.

As bodies which absorb radiant heat are necessarily heated in consequence of that absorption, to discover which of the various materials that can be employed for constructing fire-places are best adapted for that purpose, we have only to find out, by an experiment very easy to be made, what bodies acquire least heat when exposed to the direct rays of a clear fire;—for those which are least heated, evidently absorb the least, and consequently reflect the most radiant heat. And hence, it appears that iron, and, in general, metals of all kinds, which are well known to grow very hot when exposed to the rays projected by burning fuel, are to be reckoned among the very worst materials that it is possible to employ in the construction of fire-places. The best materials are fire-stone, and common bricks and mortar.

When bricks are used they should either be covered with a thin coating of plaster, which, when it is become completely dry, should be white-washed, or the covings should be lined with white Dutch tiles, or marble. The fire-stone should likewise be white-washed when it is used; and every part of the fire-place which is not exposed to be soiled and made black by the smoke, should be kept as white and as clean as possible. As white reflects more heat as well as more light than any other colour, it is aways to be preferred for the inside of a chimney-fire-place; and black, so commonly used, which reflects neither light nor heat, should be avoided. How much inferior, also, in liveliness, is the dingy black chimney of the present day, to the bright stove-grate, and white chimney of forty years ago, before the introduction of the Bath stoves.

There is, however, in chimney fire-places destined for burning coals, one essential part; the grate, which cannot well be

made of any thing else but iron; but there is no necessity whatever for that immense quantity of iron which surrounds grates as they are now commonly constructed and fitted up, and which not only renders them very expensive, but injures very essentially the fire-place.

Registers also are not only quite unnecessary, where the throat of the chimney is properly constructed, and of proper dimensions, but in that case would do much harm. Without doubt registers have often been found to be of use; but it is because the great fault of all fire-places constructed upon the common principles, being the enormous dimensions of the throat of the chimney, this fault has in some measure been corrected by them; but there never was a fire-place so corrected that would not have been much more improved, and at infinitely less expense by the alterations hereafter recommended.

The bringing forward of the fire into the room, or rather bringing it nearer to the front of the opening of the fire-place, and the diminishing of the throat of the chimney, being the two objects principally held in view in the alterations in fire-places recommended, it is evident that both these may be attained merely by bringing forward the back of the chimney as far as possible, without diminishing too much the passage which must be left for the smoke.

The back of the chimney must always be built perfectly upright: to determine therefore the place for the new back, or how far precisely it ought to be brought forward, nothing more is necessary than to ascertain how wide the throat of the chimney ought to be left.

[The direction to build the back of the chimney perfectly upright is objectionable, as will be seen on the two following pages; a jutting back from the top of the fuel when the grate is full to within three or four inches of a line corresponding with the lower edge of the mantelpiece is found to be far preferable, on account of the more favourable position of the surface for the reflection of the radiant heat into the room.]

It has been found that when the back of the fire-place is of a proper breadth, the best depth for the throat of a chimney from front to back, when the chimney and the fire-place are of the usual form and size, is four inches, and this whether the fire-place be destined to burn wood, coals, turf, or any other fuel commonly used for heating rooms by an open fire, and whatever may be its width.

Provision must be however made, at least in London, for the passage of the chimney sweeper up the chimney. This may easily be done in the following manner;—In building up the new back of the fire-place, when this wall, which

need never be more than the width of a single brick in thickness, is brought up so high that there remains no more than about ten or eleven inches between what is then the top of it, and the inside of the mantel, or lower extremity of the breast of the chimney, an opening, or door-way, eleven or twelve inches wide, must be begun in the middle of the back, and continued quite to the top of it, which, according to the height to which it will commonly be necessary to carry up the back, will make the opening about twelve or fourteen inches high, which will be quite sufficient to allow the chimney-sweeper to pass. When the fire-place is finished, this door-way is to be closed by a tile, or a fit piece of stone placed in it, dry, or without mortar, and confined in its place by means of a rabbit made for that purpose in the brick-work. As often as the chimney is swept, the chimney-sweeper takes down this tile, which is very easily done, and when he has finished his work, he puts it again into its place.

The current of air which, passing under the mantel, gets into the chimney, should be made gradually to bend its course upwards, by which means it will unite quietly with the ascending current of smoke, and will be less likely to check it or force it back into the room. This may be effected with the greatest ease and certainty, merely by rounding off the breast of the chimney, or back part of the mantel, instead of leaving it flat, or full of holes and corners.

As many of the grates now in common use will be found to be too large, when the fire-places are altered and improved, it will be necessary to diminish their capacities by filling them up at the back and sides with pieces of fire-stone.

The proper depth from front to back for grates destined for rooms of a middling size will be from six to eight inches, and their lengths may be diminished more or less, according as the room is heated with more or less difficulty, or as the weather is more or less severe. But where the depth of a grate is not more than five inches, it will be very difficult to prevent the fire from going out

Where it is necessary that the fire in a grate should be very small, it will be proper, in reducing the grate with fire-stone, to bring its cavity, destined for containing the fuel, to the form of one-half of a hollow hemisphere; the two semicircular openings being one above to receive the coals, and the other in front, resting against the bars of the grate; for when the coals are burnt in such a confined space, and surrounded on all sides, except in the front and above, by fire-stone, which is a substance peculiarly well adapted for confining heat, the heat of the fire will be concentrated, and the cold air of the atmosphere being kept at a distance, a much smaller quantity of coals will burn than could possibly be made to burn in an iron grate.

Where grates which are destined for rooms of a middling size, are longer than fourteen or fifteen inches, it will always be best, not merely to diminish their lengths by filling them up at their two ends with fire-stone, but after forming the back of the chimney of a proper width, without paying any regard to the length of the grate, to carry the covings through the two ends of the grate in such a manner as to conceal them, or at least to conceal the back corners of them in the walls of the covings.

Fig. 41, shows how the fire-place is to be altered in order to its being improved.

*A b*, is the opening in front; *c d*, the back; and *a c* and *b d*, the covings of the fire-place in its original state.

*A b*, its opening in front; *i k*, its back; and *a i* and *b k*, its covings after it has been altered; *e*, is a point upon the hearth upon which a plumb suspended from the middle of the upper part of the breast of the chimney falls. The situation for the new back is ascertained by taking the line *e f*, equal to four inches.

Fig. 41.

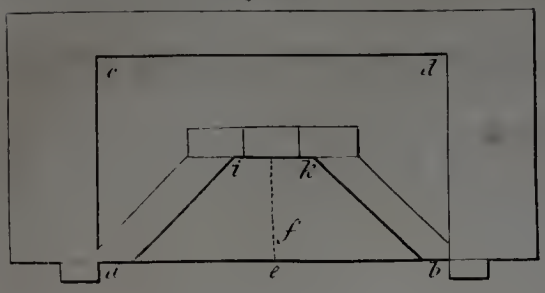



Fig. 42.

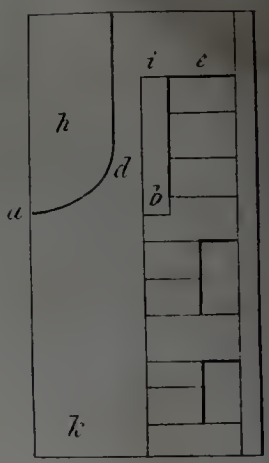



Fig. 43.

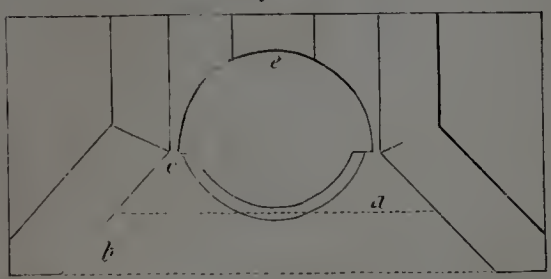



Fig. 45.

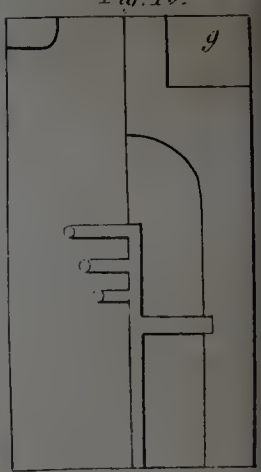



Fig. 44.

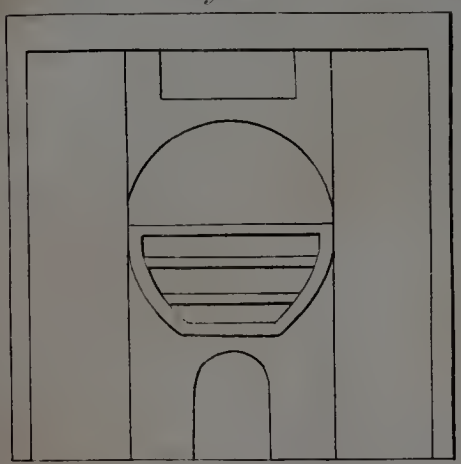
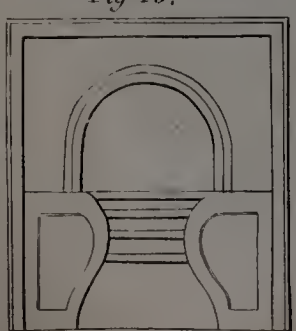


Fig. 47.

Fig 46.



The new backs and covings are represented as being built of bricks; and the space between these and the old back and covings as being filled up with rubbish.

Fig. 42, shows a section of a chimney after it has been altered; *k l*, is the new back of the fire-place; *b i*, the tile or stone which closes the door-way for the chimney-sweeper; *d i*, the throat of the chimney narrowed to four inches; *a*, the mantel; and *h*, the new wall made under the mantel to diminish the height of the opening of the fire-place in front.

In general it will be best, not only for the sake of the appearance of the chimney, but for other reasons also, to lower the height of the opening of the fire-place whenever its width in front is diminished.

When the wall of the chimney in front, measured from the upper part of the breast of the chimney to the front of the mantel, is very thin, it may happen that the depth of the chimney may be too small. In this case the depth of the fire-place at the hearth should be increased twelve or thirteen inches, and the back built perpendicular to the height of the top of the burning fuel.

Then sloping the back by a gentle inclination forward, bring it to its proper place, that is to say, perpendicularly under the back part of the throat of the chimney. This slope, which will bring the back forward four or five inches, or just as much as the depth of the fire-place is increased, though it should not be too abrupt, yet it ought to be quite finished at the height of eight or ten inches above the fire, otherwise it may perhaps cause the chimney to smoke; but when it is very near the fire, the heat of the fire will enable the current of rising smoke to overcome the obstacle which this slope will oppose to its ascent, which it would not do so easily were the slope situated at a greater distance from the burning fuel.

A fire-place having been carried back in the manner here described, in order to accommodate it to a chimney whose walls in front were remarkably thin, it was found on lighting the fire that it appeared to give out more heat into the room than had ever been witnessed. This effect was unexpected; but the cause of it was too obvious not to be immediately discovered. The flame rising from the fire broke against the part of the back which sloped forward over the fire, and this part of the back being soon very much heated, and in consequence of its being very hot, indeed, when the fire burnt bright it was frequently quite red hot, it threw off into the room a great deal of radiant heat. It is not possible that this oblique surface, namely, the slope of the back of the fire-place could have been heated red hot merely by the radiant heat projected by the burning fuel, for other parts of the fire-place nearer the fire, and better situated for receiving radiant heat, were never found to be so much heated; and hence it appears that the combined heat in the current of smoke and hot vapour which rises from an open fire may be at least, in part, stopped in its passage up the chimney, changed into radiant heat, and afterwards thrown into the room.

Figs. 43, 44, 45, show a plan, elevation, and section of a fire-place constructed or altered upon this principle.

The wall of the chimney in front, *a*, fig. 69, being only four inches thick, four inches more added to it for the width of the throat would have left the depth of the fire-place measured upon the hearth, *b c*, only eight inches, which would have been too little; a niche, *c* and *e*, was therefore made in the new back of the fire-place for receiving the grate, which niche was six inches deep in

the centre of it below, thirteen inches wide, or equal in width to the grate, and twenty-three inches high; finishing above with a semicircular arch, which in its highest part, rose seven inches above the upper part of the grate. The door-way for the chimney-sweeper, which begins just above the top of the niche, may be seen distinctly in both the figures, 70 and 71. The space marked, *g*, fig. 71, behind this door-way, may either be filled with loose bricks, or may be left void. The manner in which the piece of stone, *f*, fig. 71, which is put under the mantel of the chimney to reduce the height of the opening of the fire-place, is rounded off on the inside, in order to give a fair run to the column of smoke in its ascent through the throat of the chimney, is clearly expressed in this figure.

These improvements of our ordinary stoves, proposed by Count Rumford, have been very generally adopted in London, and few fire-places are to be seen in a sitting-room which has not been Rumfordised: but in most cases the form alone of the improvement has been seized, and the most essential points neglected, to please the eye. The sides and back of grates are still made of iron, the side-fronts, hobbs, and covings, are of the same so highly improper material, and covered with a black lugubrious coating, instead of being lined with white Dutch-tiles as formerly, or the large cream yellow earthen-ware-tiles used for paving in some parts of Wales; either of which could be washed clean with a little soap and water: in elegant rooms the covings might be made of white, or rather yellow marble, which is most agreeable to the eye.

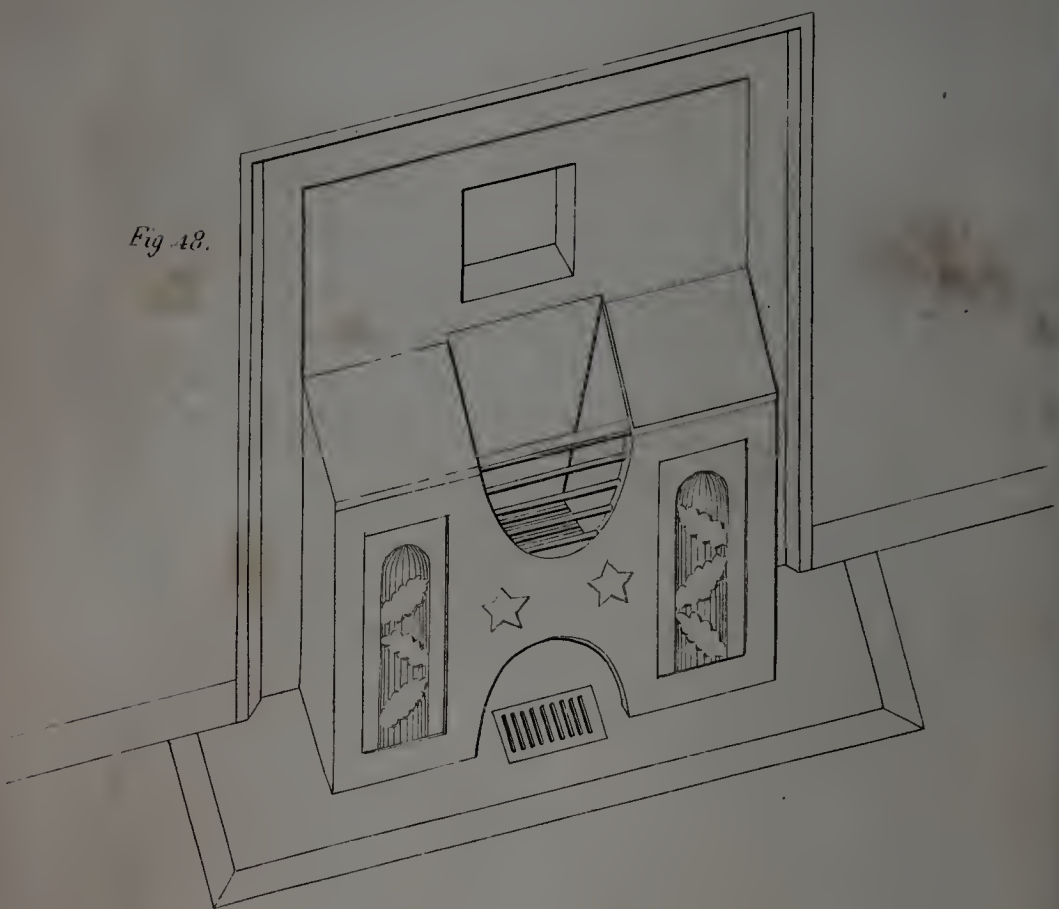
Mr. Tredgold is of opinion that the grates of open fire-places ought to be one-twelfth the length of the room; and if this is more than thirty feet in length, two fire-places will be requisite. The depth from front to back cannot be less than six inches; and if the breadth of the room exceeds twelve feet, an additional half inch may be added to the depth for each additional foot of breadth in the room.

The round lumps of baked clay, or fire-balls, sometimes put into the fires of common grates, to diminish their intensity, are extremely troublesome to manage, and the fire soon goes out, if it be not carefully minded: hence they are worse than useless. They must not be confounded with the fire-balls to be used as fuel, especially as there is reason to think that their being called by the same name, has tended to prevent the introduction of the latter.

### *Irish Stoves.*

Mr. Buchanan, in his Essay on the Economy of Fuel, relates, that on landing in Ireland, he was struck with the excellent construction of the fire-grate in his room at the inn where he lodged. He at first thought it was an invention of his landlord's, but on proceeding on his journey, he found

Fig. 48.



these kind of fire-grates very common in that part of Ireland.

Figs. 46 and 47, represent the one a front view, and the other a transverse section from front to back of these fire-places, which appear well calculated to remedy the smoking of chimneys, and, at the same time, to lessen the consumption of fuel. The fire-room is wide and shallow, in order to present the greater surface of fire to the room, that by its radiation it may throw out the greatest possible quantity of heat. The upper portion of the chimney recess is partly closed by an upright slab of fire-stone, in which is cut an arch. The back wall is formed of fire-stone, or fire-brick, into an oval niche, and the throat of the chimney is made very small, to increase the velocity of the air, and thus enable it the better to carry off the smoke.

### *Staffordshire Stoves.*

Somewhat similar to this is the usual manner of setting grates in the sitting-rooms in Birmingham and its neighbourhood.

Fig. 48, represents this mode of setting grates. The usual recess built in rooms for the insertion of whatever grate or stove the occupier may bring in, is built up by a wall in front even with the mantel-piece; and only a small opening is left for the passage of smoke into the chimney, just above the back of the grate, which is placed against this wall, and projects entirely into the room.

The dimensions of the opening for the passage of smoke varies but slightly according to the size of the grate, and is usually about nine inches square.

If the recess of the chimney is very large, as when the kitchen of an old house is converted into a sitting-room, or the occupier is desirous of practising economy, a flue is built up at the back to meet the throat of the old chimney; the new grate is placed against this flue, and the sides of the old recess serve as open closets for things that require slow drying, or being kept dry and warm.

These methods of setting stoves in open fire-places, may certainly be considered superior to that of the American chemist, Count Rumford, originally Mr. Benjamin Thompson.

There is, from long custom, so great a desire amongst all ranks in England, to see the fire which warms their apartments, that the most convenient, cleanest, and cheapest methods of heating them are sacrificed to this single circumstance. Yet, no one who has considered the subject, can have the slightest hesitation in saying, that heating apartments, either by close stoves, ovens, or steam-pipes, which radiate heat from their sides, or by a current of warm air, heated in the lower part of the house and ascending to the upper apartments, is far preferable, if the necessary attention is paid to cleanliness, to the rude and unphilosophic method of heating rooms by open fire-places.

The currents of air in rooms heated by the ordinary open fire-places, are frequently a complete nuisance; and independent of these currents, as the occupiers of the room are always between the fire-place and the source from whence the air comes, it is impossible to preserve an equality of temperature throughout our whole frame, as sometimes even one part of the body is roasting, while the other parts are freezing.

Not but that it is certainly an overstrained idea of comfort to suppose an absolute equality of heat in our apartments desirable. This equality does not exist in nature; the sun warms us by radiant heat, and, consequently unequally; we never feel heat oppressive nor injurious till the air becomes hot; and if there be an inconvenience in that inequality of heat, which we must be sensible has place every time the sun shines, it is an inconvenience that has never been felt; the cool freshness of the air, and the warmth of the sun's rays, are sensations most pleasurable when united. Plants, in the natural state, are also exposed to this inequality of temperature: those who have cultivated them with most success, have found that uniform heat is not desirable, when it is applied artificially. An imitation of nature in treating plants, has been attended with sufficient advantage to show that it is the proper course to be followed.

[*American Grates for Burning Anthracite Coals.*

The greater difficulty of burning the anthracite coals, now extensively used in our Atlantic cities, has suggested an alteration in the construction of the common grates, which is so simple, and so decidedly preferable to the usual form, that it is not a little remarkable that it has never before been adopted; it consists in placing the front bars of the grate in a vertical, instead of a horizontal position; the bars at the bottom of the grate run in the usual direction, (i. e. from front to back,) and are merely continuations of the vertical part bent at right angles at the bottom, and front of the fire-place. This arrangement is much more favourable for the admission of air to the burning fuel than the common method; indeed it has been found nearly impossible to burn the anthracite coals in the usual English grates. The construction of stoves and grates for the combustion of this fuel has become an object of such great practical importance, that I cannot refrain from quoting the following judicious remarks from Mr. Bull's "*experiments to determine the comparative loss of heat sustained by different constructions of apparatus ordinarily used for the combustion of fuel.*]

"The difficulty of consuming small quantities of anthracite coal in open grates, must operate to prevent its general introduction into use, unless this difficulty can be removed; any suggestions, therefore, which may possibly tend to lessen this objection to an article of such vast importance to the community, will not be considered irrelevant to my subject.

"It is very well known, that no particular difficulty is experienced, under ordinary circumstances, in consuming small quantities of this coal in sheet iron cylinder stoves lined with

fire-brick, and it is as well known, that an equally small quantity of this coal cannot be consumed in an open grate. The inference, therefore, which should be drawn from the knowledge of these facts, is, that the open grate is an apparatus not properly constructed to obtain the desired object, independent of the deleterious gas which it imparts to the room. The question which then presents itself, is, what are the qualities possessed by the former apparatus in which the latter is deficient?

"In the former, the coal is known to be completely surrounded by a thick substance, which, when heated, retains its heat with great tenacity. The air admitted is in small quantity, and, from the construction of the stove, it is necessarily considerably elevated in its temperature, before it comes in contact with the burning body. We infer from these facts, that anthracite coal requires a very high temperature to produce ignition, and, as we know that combustion cannot take place without this prerequisite, the necessary means to effect it, are, consequently, indispensable. We also infer, that the commonly received opinion, that this coal requires a very large quantity of air, or "strong draught," to carry on its combustion, is not correct; the converse of this opinion being nearer the truth; and this may in part be demonstrated by an examination of a single piece of this coal which has been ignited. If we break the piece of coal, the interior will present its original black colour and lustre, with the exception of an inconsiderable portion near the surface; the body of the coal being sufficiently dense to exclude the access of air, no cumbustion of its interior can take place, and, consequently, the quantity of air necessary to be admitted to the coals, is nearly proportional to *their surfaces*, but not in proportion to their positive quantity, as would be nearer the case, if this article were as pervious to air as charcoal. Any excess of air, therefore, is injurious in proportion as the quantity exceeds that which can unite with what is termed the combustible or base, inasmuch as it tends to reduce its temperature, and thereby renders it less capable of rapid union with the air, to produce the combustion; and as each successive portion of air in excess robs the combustible of its heat, we see the fire languish for a short period, and then expire.

"Although atmospheric air is generally necessary to support combustion, an excess of it, it is well known, will, in some cases, extinguish a burning body, as expeditiously as water; and from this circumstance it may be inferred, that for ignition, the air requires to be heated as well as the combustible body. We may also infer, that the intensity of heat produced by the union of the two bodies will be proportional to the excess with which their united heats exceed their mean heat of ignition.

"Having had occasion, during the past winter, to warm two warehouses, of different sizes, and it being necessary that the temperature should be permanent during the night season, two cylinder sheet iron stoves of ordinary construction, and of different sizes, lined with fire-brick, were procured, which were supplied with Lehigh coal.

"The construction of the stoves being favourable to apply on a large scale what I had found so advantageous in my expeririment stove, there being considerable space between the grate and the bottom of the ash-pan, this space was converted into a reservoir for heating the air, by closing the apertures usually made for its admission in the front of the ash-pan. During the igniting process, the ash-pan was drawn out, but when this was effected, it was closed as perfectly as its construction would admit, leaving only the small crevices at its junction with the body of the stove for the admission of air, and although the largest stove usually contained more than half a bushel of coal, this supply of air was found sufficient for producing intense combustion, and the quantity of coal remaining on the grate unconsumed, was found to be much less than when the stove was supplied with a larger quantity of air; a very important saving was thus made in the heat, by diminishing the quantity and the velocity with which the current of heated air passed into the chimney. Very important improvements may be made in the construction of sheet iron stoves, for burning anthracite coal; and, if provision is made for supplying the burning body with *intensely heated air*, any required quantity of coal may be consumed, and the present manner of lining them with thick brick may be entirely dispensed with, by substituting either thin tiles, or a thin coating of clay lute, sufficient to preserve the iron from fusion or oxidation, and, as this would present less obstruction to the speedy communication of the heat generated to the air of the room, consequently less would escape into the chimney.

"In examining the construction of the open parlour grate, we do not find in it one entire quality possessed by the close stove: the only one which bears any approach to similarity, is, that three sides of the grate are lined with fire-brick; but, as the fourth is almost wholly exposed, its utility is thereby defeated.

"It is admitted that the combustion is very perfect and rapid, when the sheet iron door, or "*blower*," as it is technically termed, is applied to close the front of the grate; and this must be a necessary consequence, as its application transforms the open grate into a powerful *air furnace*, by which the space for the admission of air is very much reduced, and the air is probably reduced in quantity, this not being compensated by its increased velocity, and as the blower defends the body of coal

in front from the cold air, to which it was before exposed, the required elevation in temperature is effected and maintained without difficulty.

"It is only by radiation that any heat is imparted to the room from coal consumed in open grates, and as the radiated heat is known to be very small from the surface of that portion of coal which is exposed to the front or open part of the grate; the amount of heat imparted to the room would not probably be diminished, but rather increased, by using a thin plate of cast iron for the front of the grate, by which the difficulty of consuming small quantities of coal would be very much diminished; and this would not be less agreeable in its appearance than the equally *sombre* aspect presented by the unignited coal in the front of the generality of small grates, and particularly as the top of the coal would be exposed to view, and present a more luminous appearance.

"Although iron is a good conductor of heat, the plate suggested would become sufficiently heated to maintain the temperature of the coal necessary to carry on the combustion of the surface exposed to it, with the exception of the points actually in contact with it, which would be unimportant; and this being the case, its conducting power would, in other respects, be obviously advantageous, and no danger of melting the iron, in this situation, need be apprehended. If, however, danger from melting or oxidation of the iron is feared, as a flat plate of iron could not be permanently covered with any composition of clay, it should be made circular, and defended at the top and bottom by a flange projecting on the inside, the required thickness of the clay. In addition to the plate suggested to cover the front of the grate, a still farther improvement might be made by enclosing the ash pit also, both of which might be done with one plate of iron, and the grate for sustaining the coal might rest upon cleats projecting from the interior, taking care to give sufficient room for the expansion of the grate, to prevent the plate being pressed outwards. A door for the removal of ashes and the admission of air would be required, by which the necessary quantity of air could be admitted without an excess. This construction would also be favourable for heating the air which is to supply the combustible body, the advantage of which must be obvious, when we reflect on the necessity of cooling the burning body as little as possible. By the greater expansion of the air, the quantity which comes in contact with the burning body would be less in excess, at any one time, and better adapted to attain the object; the contact being more frequent, from its increased velocity, the quantity actually united in any given time, would probably be greater, and more heat would consequently be pro-

duced. This construction, besides the advantages already stated, would be more cleanly than the open grate, would not require the blower, and could also be made use of for culinary purposes, which is a very desirable object to be attained.

"The construction of many grates is very objectionable, in an important particular not yet noticed, which is, making the receptacle for the coal of greater length than it has breadth or depth, by which the body of coal is not as much heated, and requires to be replenished more frequently to maintain the relative position of the coal, necessary to continue the combustion. A much better shape, and which would require less coal at any one time, would be in the proportions of twelve inches deep, to eight inches square at the top, and gradually diminished to six inches at the bottom, by which the heat generated in the combustion of the coal at the lower part of the grate, in its passage to escape into the chimney, would come in contact with nearly the whole body of coal, and keep it heated, which cannot be the case in the former shape, supposing the contents of the two grates, and the coal in each to be equal; and if we suppose them to be only *half filled* with coal, the position of that in the deep grate, although less in quantity, will be very favourable for combustion, while that in the shallow grate, from the unfavourable situation in which it is placed, would scarcely burn at all. The advantage of placing the body of coal in a deep grate, as described, may be illustrated by the well known fact, that a stick of wood burns much more rapidly in a vertical, than in a horizontal position, and for the reason already assigned.

"Being well aware of the strong predilection in favour of those constructions which will permit the burning body to be seen, which, with other reasons prevents the use of close stoves in many instances, and particularly where elegance is required, the necessity is apparent, that some new construction should be devised, which can be substituted for the open grate, and which will obviate the difficulty, not only of consuming anthracite coal in small quantities, for rooms of small dimensions, but, the still greater objection generally made to its use, that the quantity cannot be varied to meet the changes in the temperature of the atmosphere.

"In the plan which I will venture to suggest, a partial compromise must be made in the first particular stated, but all the others may be realized.

"In those instances where simplicity of construction is required, take a cylinder, or, rather, an inverted conical frustrum, of cast iron, of any required thickness and diameter, and of sufficient height to form the receptacle for the coal and ashes; insert a grate at a sufficient height from the bottom to leave the

required room for the ash pit, which should be provided with a door to remove the ashes and unconsumed coal, as is usual in close stoves, and, also, to regulate the admission of air, which may be heated as in those stoves. This cylinder may be bricked in the ordinary manner on the outside; and this can be done with greater facility than for the grate, and the cylinder will remain more permanently fixed, as it will rest on the hearth. From the satisfactory experiments which have been made in double cylinder stoves, in which the interior cylinder is made of cast iron, without any coating of clay, it is not probable that this construction would require it. In those instances in which beauty of construction must be consulted, the ornamental parts or appendages to the open grate may be added; the only change suggested being the substitution of a cylinder, or other more desirable shape, of cast iron, in place of the open grate."

[*American Fire-Places for Burning Wood.*

The hearth is on a plane with the floor of the room, in which the fire-place is situated; the jambs, or vertical sides of the fire-place, should form an angle with the back of 135°; the back wall should rise perpendicularly one half the distance from the hearth to a line on a plane with the lower edge of the mantel-piece, and then form such an inclination forward as shall bring it within four inches of the mantel when it has attained to that height, where it terminates; the mantel-piece should be smooth on its inner and back surface, and form a segment of a circle from its lower and front edge to the uppermost posterior edge. The dimensions of the fire-place must vary with the size of the apartment to be warmed; one whose mantel shall span 41 inches from jamb to jamb in front, and whose depth from back to front on the hearth shall be 12 inches, and height from hearth to mantel 33 inches, will warm a room twenty feet square and ten feet high, or four thousand cubic feet of air. A fire-place of this construction embraces all the valuable improvements of Count Rumford and Dr. Franklin: its surfaces are so disposed as to be highly favourable for the reflection of the radiant heat, by which our apartments are principally warmed by open fire-places of almost every description; the rays of caloric, which emanate from the burning fuel, impinge upon the jambs and back, at such an angle as to be reflected into the room. Owing to the height of the mantel-piece, the great extent of surface, as well as the position of the back and jambs is favourable also to the radiation of that portion of heat, which is absorbed by them. The parts, which are exposed to a temperature approaching a red heat and above, should be constituted of brick, or soap-stone; but the front of the jambs and the mantel-piece may be

formed of free-stone, or marble, at the pleasure of the architect. The lighter the colour and the more polish there is upon the jambs the more of the radiant heat will be reflected, and the less absorbed in the first instance.

### *American Double Fire-Place.*

A recent improvement upon the Rumford plan is what has been called the double fire-place. To understand its construction it is only necessary to suppose a fire-place of the same form and dimensions as the one last described, set within another of sufficient size to receive it and leave an open space between the hearths and walls of each of from 1 to 1½ inches in width; some builders make the mantel-piece hollow, also; in which case the included space communicates with the one between the walls. This enclosure has two openings, one communicating with the external air through the back of the chimney, or through an iron pipe laid for that purpose, of from 1 to 2 inches diameter, and the other with the air of the room at the side of the chimney a little above the mantel. The interior or smaller fire-place is constructed of slabs of soap-stone, of from 1½ to 2 inches in thickness, accurately jointed and fitted together. The advantages proposed by this construction over the common Rumford fire-place are two-fold;—first, to secure a ventilation of the room by fresh warm air, and secondly to save that heat, which in the usual construction is absorbed by the walls, and lost by slow communication through the back of the chimney. These objects are certainly secured, but the construction of these fire-places is attended with considerable additional expense; they are more liable to fall out of repair, and their use will probably, for the most part, be confined to the apartments of the rich.

Much has been said and written concerning the great waste of fuel, in even the best constructed fire-places, when compared with other methods of warming our apartments. Dr. Franklin estimated that in the deep low fire-places in use in his day, ninety-five *per cent.* of the heat generated by the combustion of the fuel escaped up the chimney, and was lost. Mr. Bull, in his recent experiments, estimates the loss in a fire-place of "ordinary construction," (by which I understand a fire-place on the Rumford plan,) at ninety *per cent.* The following table contains the results of Mr. Bull's experiments on the combustion of perfectly dry wood in five of the most usual forms of apparatus in use. I extract it by permission from his interesting paper, from which I have already quoted largely in different parts of this work.

*Table exhibiting the results of experiments made to determine the comparative loss of heat sustained by using apparatus of different constructions, for the combustion of fuel.*

| Description of apparatus used. | Time the room was maintained at the same temperature, in the combustion of equal weights of fuel, compared with apparatus No. 9. | Weight of fuel required by each apparatus, to maintain the room at the same temperature, and for the same time, compared with No. 9. |
|---|---|---|
| No. 1. CHIMNEY FIRE-PLACE, of ordinary construction, for burning wood, . . | 10 | 1000 |
| 2. OPEN PARLOUR GRATE, of ordinary construction, for burning anthracite coal, . . . . . | 18 | 555 |
| 3. OPEN FRANKLIN STOVE, with one elbow-joint, and 5 feet of six inch pipe placed vertically, the fire-place being closed with a fire-board, . . . . | 37 | 270 |
| 4. CAST IRON TEN PLATE STOVE, with one elbow-joint, and five feet of four inch pipe, placed horizontally, entering the fire-board, . . . . . | 45 | 222 |
| 5. SHEET IRON CYLINDER STOVE, the interior surface coated with clay lute, with one elbow-joint, and 5 feet of two inch pipe, placed horizontally, entering the fire-board, . . . . . | 67 | 149 |
| 6. SHEET IRON CYLINDER STOVE, as before described, with 13½ feet of two inch pipe, in which there were 3 elbow joints, the whole placed as follows: 3½ feet horizontally, 5 feet vertically, for an ascending current, and 5 feet vertically, for a descending current, entering the fire-board, . . . . . | 78 | 128 |
| 7. SHEET IRON CYLINDER STOVE, as before described, with 13½ feet of two inch pipe, in which there were 3 elbow-joints, placed as follows: nine inches vertically, and 12¾ feet horizontally, entering the fire-board, . . . . . | 82 | 122 |
| 8. SHEET IRON CYLINDER STOVE, as before described, with nine elbow-joints, measuring 13½ feet of two inch pipe, entering the fire-board, . . | 95 | 105 |
| 9. SHEET IRON CYLINDER STOVE, as before described, with 42 feet of two inch pipe, as used in the course of experiments on fuel, . . . . . | 100 | 100 |

It will be perceived, that, in the above table, Mr. Bull proceeds on the assumption, that in No. 9 (which was the same stove as used by him in his experiments to determine the comparative heat produced by the combustion of equal weights of the principal varieties of fuel in the United States) there is an entire saving in the apartment of the heat produced in the combustion. The arrangement, indeed, affords as near an approximation to such a result as is possible to conceive of obtaining by any means whatever, unless it be by burning the fuel in the open room without the use of a chimney; for, a thermometer, the bulb of which was inserted into the pipe just before it entered the chimney, indicated the same temperature as one which was suspended in the room without the pipe, at the same elevation from the floor: no portion of the sensible heat, therefore, was lost by the flue, except that part which was contained in the air which supported the combustion. The results in the first column were obtained by actual experiment, and those of the second column by common proportion.

The effect of position, and increasing the number of elbows or turns in the pipe, is strikingly shown in Nos. 6, 7, and 8, in which the stove, the length of the pipe, and every other circumstance are the same. These effects are reasonably attributed, by Mr. Bull, to the retardation, and the sudden and abrupt changes of the currents of heated fluid in the pipe, by which the relative position of the different portions are more frequently changed, and the hotter particles of the interior of the current are brought successively to the surface, and, after imparting their heat to the pipe, give place in their turn to others.

If the attainment of a given temperature in our apartments, at the least expense of fuel, were to be the only circumstance in determining our choice of one of the usual means of effecting that object, no one could hesitate for a moment to adopt the close stove, with a sufficient length of tortuous pipe. But the open fire-place, though far more wasteful of fuel, possesses compensating advantages, which always have, and always will render it a favourite in our parlours:—the cheapness and simplicity of its construction, the perfect ventilation which it affords the apartment, the cheerfulness produced by the sight of the fire, and the comforts of a warm hearth, are circumstances which strongly recommend it. The difference in the expense of supplying the open fire-place and the close stove is by no means so great in actual practice as we should infer from experiment; for people are generally willing to accept, and do, in fact, cheerfully submit, to a much lower temperature in their apartments in the use of the former than they will do with the latter. The practical advantage derivable from warm feet will, in the minds of many, more than compensate for the difference in the expense of fuel necessary to supply each.

The open parlour stove, with a short flue, is an apparatus possessing properties intermediate between the close stove and open fire-place, both in respect to economy of fuel, and pleasantness in use.]

### *Close Stoves.*

There is yet another mode of distributing heat, which has the advantage of preventing the air being in contact with a surface heated above 212 degrees. It consists in confining the burning fuel within a proper thickness of matter, generally of a slow conducting power. The material usually employed is brick, or fire-stone; and the flues of hot-houses have always been formed in this manner, whether from principle or convenience it is difficult to ascertain. The extent to which heat can be carried by this method is very limited; but if the materials are unexceptionable, it is much the best and most simple method of heating air on a small scale.

The various forms of close stoves, called Swedish, &c. are only variations of this method.

The use of them, in the northern parts of Europe, is indispensably necessary, as without them it would be impossible to keep their rooms warm. These stoves retain the heat a long time; and as their external parts, and also their flues, are very thin, they communicate their heat very readily, so that with a small quantity of wood, they warm an apartment much more than the fire of a common fire-place would do with six times the quantity.

[It is certainly a mistaken idea of the author, that close stoves fabricated of brick, stone, or pottery ware, can possess superior properties to iron ones of similar construction for conducting and diffusing heat; it is directly opposed to the best established facts in relation to the laws of caloric. Stoves, however, constructed of these materials, possess some advantages over those of iron; they afford a more equable and pleasant heat, owing to the inferior conducting power of their material, and its superior capacity for heat, apartments warmed by these stoves are not subject to those sudden alternations of temperature that iron ones occasion. When the temperature within is intense, their walls absorb and retain more heat, and impart it more gradually to the room when the fire burns low. Yet, by increasing the length and convolutions of the flue in an inverse ratio to the conducting power of the walls, when composed with iron, the same, or nearly the same, amount of heat may be obtained. These stoves are not subject to the unpleasant smell attendant on those constructed of iron, which is owing to the decomposition of minute particles of dust, and other matters, which come in contact with a surface of quick conducting power. A few years since brick stoves constructed on the Russian

plan, were very common in New England. Some popular writer, or circumstance, not now recollected, produced a strong sentiment in their favour, and almost every inn, and thousands of private dwellings, were furnished with one or more of them; but their popularity was short, and they have now fallen into very general disuse. The cause of this sudden revulsion of public opinion is to be attributed partly to the extravagant expectations, which were first formed of their utility, and partly to the very clumsy and imperfect manner in which they were frequently constructed. The one above described, appears well adapted for securing the peculiar advantages derivable from this method of house-warming.]

The stoves perfectly fulfil the above-mentioned intentions; they are also susceptible of every kind of ornament; and nothing can be handsomer than the stoves of pottery-ware that are to be seen in French Flanders, or the Russian stoves finished in stucco.

The more surface we give to a stove constructed in this manner, the more the heat is increased, consequently we must not be surprised to find that this kind of stove sometimes occupies the whole height of an apartment, its width and depth being proportioned to its height.

Fig. 49, represents one side of the stove: *a*, is the door by which fuel is introduced, and through which the fire is lighted. In this door there is usually a very small wicket shut by a slider.

Fig. 50, is a transverse section of the same stove, about one third of its length from the side in which the feeding-door is placed; *b*, is the cavity, in which the fuel is placed, and which may properly be called the fire-room. It is separated from the hollow space, *c*, left under the stove, by an earthen floor; *d*, are cavities which serve to collect and retain the heat, and also to form passages for the smoke; *e*, is another cavity which has no communication with the interior cavities, consequently affords no passage for the smoke: this cavity is formed in the highest part of the stove, and is used as a kind of pan in which to dry articles: but it collects dust, and a plain flat surface is far preferable for the top of these stoves.

The construction and the direction of the smoke will be better understood by considering fig. 51, which represents a section of the stove from side to side, about one-third of its depth from the front to the back.

*H*, shows the fire-place charged with wood, and the course of the smoke. The roofs, *k*, of the three uppermost cavities, are formed of earthen tiles. Two of these roofs do not reach quite across, but are continued only a little more than three quarters of the whole space, and are supported at their extremities, *l*, by pieces of iron fixed in the stove. By this means the smoke finds a free passage, and follows the current of the air.

The course of the smoke appears more clearly in fig. 52, being a transverse section of that part of the stove that is the farthest from the feeding-door. In this section, *m*, represents the flues for the smoke. On a level with the upper part of the cavity for the fuel or fire-place, and in the last of the flues, is fixed a trap, *n*, which is to be closed when the fuel is thoroughly red hot; by which means its farther combustion is prevented, and all the heat is confined in the stove, from which it spreads itself into the apartment. But, as when the air of the atmosphere is very cold, it would be apt to communicate a portion of its coldness to that which is near the valve, *n*, a second trap is placed in the exterior part of the chimney where it is carried up beyond the roof of the build-

Fig. 51

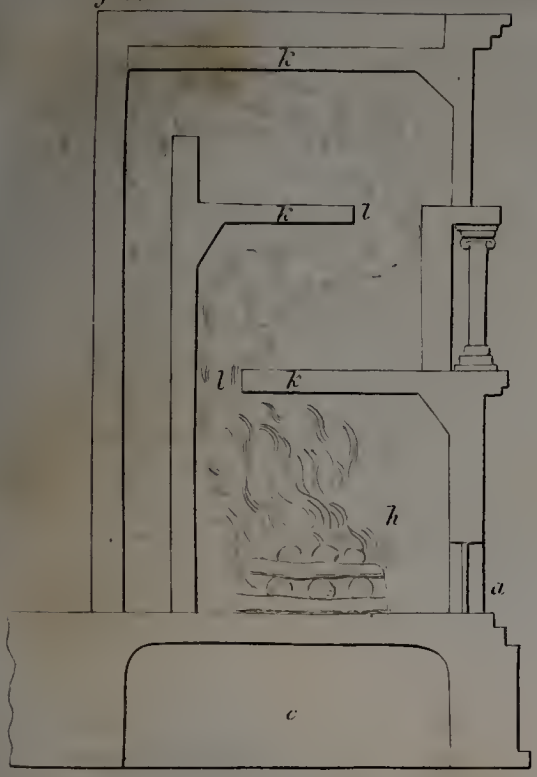



Fig. 52

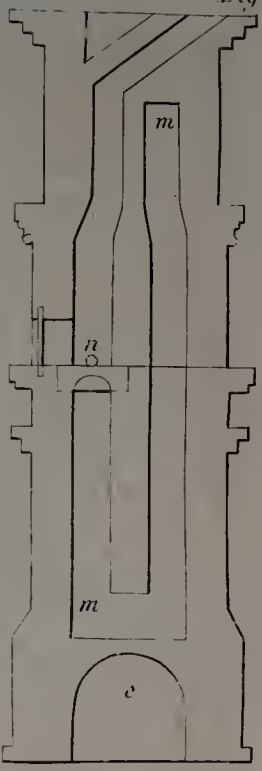



Fig. 49

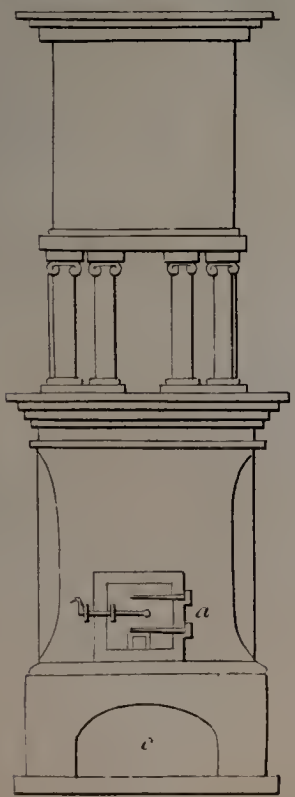
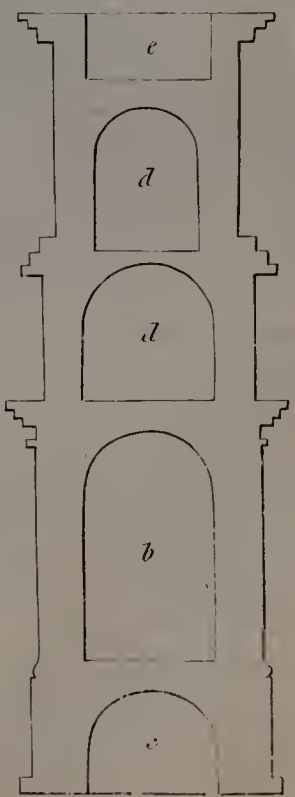



Fig. 50



ing. By means of an iron rod communicating with both valves, the operation of opening and shutting them is rendered very quick and easy.

The more usual way, however, of shutting up this passage is by a sort of pan or bowl of earthenware, which is whelmed over it with its brim resting in sand contained in a groove formed all round the hole. This damper is introduced by an opening in the front, which is then shut with a thick earthen stopper. The whole is set on low pillars or arches, so that its bottom may be a few inches from the floor. It is usually placed in a corner; and the apartments are so disposed that their chimneys can be joined in stacks as with us.

Some straw or wood shavings are first burnt on the hearth at its farther end. This warms the air in the stove, and creates a determined current. The wood is then laid on the hearth close by the door, and piled up. It is now lighted, and the current being already to the vent, there is no danger of any smoke coming out into the room. Effectually to prevent this, the door, *a*, is shut, and the wicket opened. The air supplied by this being directed to the middle or bottom of the fuel, quickly kindles it, and the operation goes on.

The aim of this construction is very obvious. The flame and heated air are retained as long as possible within the body of the stove by means of the long passages; and the breadth is necessary below, that there may be room for fuel. If this breadth were preserved all the way up, much heat would be lost, because the heat communicated to the partitions of the stove does no good. By diminishing their breadth the proportion of useful surface is increased.

It is with the same view of making an extensive application of a hot surface to the air that the stove is not built in the wall, nor even in contact with it, nor with the floor; for by its detached situation the air in contact with the back, and with the bottom, where it is hottest, is warmed and contributes at least one-half the whole effect. The great heat of the bottom makes its effect on the air of the room at least equal to that of the two ends. Sometimes a stove makes a part of the wall between two small rooms, and is found sufficient for both. In the better kind of houses, the stoves are placed next the passages and landing-places, so that they may be filled with fuel, and heated morning and evening, without the servants coming into the room; by which means much dirt and other inconveniences are avoided.

If this manner of constructing stoves be compared with the common German stoves used in English workshops, the great superiority of this stove, used by the northern nations, will be perceived, not only in respect to the quantity of heat it produces, but also with respect to the expense of fuel.

A fire lighted in a stove of this kind in the morning and the evening, with a small quantity of fuel, retains a strong heat during the whole of the day and night. Besides, these stoves are free from many other inconveniences which attend the common ones.

It may perhaps be objected, that the heat produced from these stoves must be unwholesome, as they deprive the air of its moisture, and that the air by being made too dry loses its elasticity; in consequence of which, respiration becomes difficult and laborious. These objections would appear of great weight, if we had not the example of the Russians, the Swedes, the Danes, the Germans, and in short, of all the inhabitants of the north of Europe, to show that those who are habituated to such stoves do not find them unwholesome.

The inconveniences here mentioned are indeed entirely removed by the following very simple method, which has been tried for ages, and invariably found to answer:—A vessel of glass, earthenware, &c. which has a large surface, and is very shallow, is placed on the stove and filled with water. This water insensibly evaporates, and restores to the air that moisture which the heat of the stove has deprived it of.

If orange-trees are exposed to the heat of such a stove, and the fire is not properly regulated, the plants grow yellow and lose their leaves, especially if the air is not changed, which in winter is not very conveniently done; but if a vessel of water be placed upon the stove, the evaporation of the water will preserve the trees.

It appears from the remains of the Roman villas that have been found in England, that houses, or at least the rooms attached to the baths which constituted their great luxury, were heated upon a similar principle. Except that the stove, or hypocaustum, was not placed in the room but under ground, so that it only communicated its heat by its upper surface, which formed the floor of the room, and was of equal extent with it.

The hypocaustum was in fact a low-roofed cellar with pillars in the centre, and a hollow flue round it to support the pavement of the room above it. A door near the floor served for the introduction of the fuel, and occasionally, no doubt, for the entrance of the stove-tender to clear out the soot. As three of its sides, and sometimes the greatest part of the fourth, were contiguous to the soil, there would be little expenditure of heat through them, and consequently nearly the whole force of the fire would be directed upwards into the apartment over it.

In the northern parts of Asia the Chinese and Tartars have adopted this mode of warming their apartments by the radiant heat of close stoves, as they are usually called.

The close stoves in the Chinese houses are most commonly, like the Roman, placed under the floor.

Fig. 53, represents the construction of these floor flues; *a*, is a large ash-pit sunk in the ground, for its whole depth; *b*, an opening in the front part of the roof of the ash-pit to allow the entrance of air to the fire-room, and occasionally serving as a man-hole, to allow a person to descend into the pit and clear

it of the ashes; *c*, the feeding-hole of the fire-room usually left open; *d*, the stoking-hole, which is also left, in general, open. At the back of the fire-room is a long narrow vent placed, not horizontally as in our melting or founder's furnaces, but vertically, and its length is nearly equal to the whole depth of the fire-room.

The smoke and heated air pass through this vent into a deep narrow main flue, *f*, which runs across the seat of the room, from the wall where it enters to nearly the opposite side, and has generally two side branches from about the middle of its length reaching to the other two sides. This deep flue is covered with bricks, but there are left on the sides openings through which the smoke may escape. These openings are made in the cross branches, rather than in the main flue itself.

The pavement of the room is double, the lower pavement is, however, in some cases, made only of clay and sand well beaten down. The upper pavement is of large square tiles, supported at the distance of a few inches above the lower pavement, by cubic bricks. Two horizontal flues, *l*, are constructed between the double pavement, one on each of two opposite sides of the room. These flues allow the entrance of the smoke and hot air which has circulated between the double pavement into one end, *m*, and discharge it into the chimney, *n*.

Great pains is taken in cementing the pavement to prevent the smoke from entering the room. In the royal apartments the tiles are of porcelain, two feet square, and laid double, with the joints of the one not coinciding with those of the other.

There are several various ways of building these floor smoke-flues, called koa kang, and ti kang by the Chinese.

In the best houses the furnace is built either in the court yard, and generally against the wall that faces the north, or in a servants' hall adjoining the room to be heated. And the chimneys are built on the outside.

In the houses of the poor the furnace is built in the room, and has a boiler set upon it to supply the family with water. The chimneys are also built up in the room, for being very thin they add to the effect.

The Chinese have also a kind of these stoves, which they call a tong kang, or wall stove. The north, or back wall of the house being made double, but tied together by long bricks, and thus assimilating to the cellular walled hot-houses of our gardens.

In the best houses they burn nothing but wood, or a kind of coal which does not smoke, but burns like tinder: the middling class burn pit-coal broke into the size of coarse gravel, mixed with one third, or even one half, of a yellow clay, and made up into bricks; the poor in the country use furze, straw, cow dung, or whatever they can get.

The Chinese are led by their philosophy to endeavour to sweeten the air from the noisome vapour of the fire, and to absorb the fiery particles dispersed throughout the air of the room, by keeping bowls of water in them. The gold fishes which are kept in these bowls are both an ornament and an amusement.

There can be no doubt but that the floor smoke-flues might be advantageously adopted in England in labourers' cottages, and the ground floors of houses, especially of those which are seated in a moist soil.

Father Gramont, the missionary, to whom we are indebted for this information, has omitted to state whether the fire is allowed to burn until the fuel is consumed, or whether, as in the close stoves, so soon as it is in complete combustion, the outlet

of the furnace is stopped, and the heat already produced left to radiate slowly through the walls. He only says, that very little fuel is required, and that although the open air at Pekin, is in winter, at —9 to —13 degrees Reaumur, and the fronts of the houses, which generally face the south, are scarcely any thing but oiled paper windows, two of the upper panes of which, at different ends of the room, are always left open for ventilation, yet the rooms are at 7 or 8, of Reaumur's own scale.

### *Smoke Flues for Plant Houses.*

The most general mode of heating houses for keeping plants is by fire and smoke flues, similar to the Swedish and Chinese stoves, and, on a small scale, this will probably long remain so: for with good air-tight flues, formed of well-burnt bricks, and tiles accurately cemented with lime putty, and arranged so as the smoke and hot air may circulate freely, every thing in culture, as far as respects heat, may be perfectly accomplished.

Where a house of considerable length and contents is to be heated, it is generally deemed better to increase the number of furnaces than to increase their size; for, when the latter practice is resorted to, they are necessarily projected so far into the shed, or otherwise kept back from the house, that a great part of the heat is lost in the mass of brick-work which surrounds them. Small furnaces, on the contrary, may be built in great part under the walls or floor of the house.

In countries where turf, wood, or inferior coal is used for fuel, the chamber of the furnace must be large; on the contrary, when the best coal, cinders, charcoal, or coke, which three last are the best fuel for hot-houses, as having no smoke, is used, they may be made smaller in proportion to the different degrees of intensity of the heat produced by these different materials.

In fixing on the situation of furnaces, care must be taken that they are always from one to two feet under the level of the flue, in order to favour the circulation of the hot air and smoke, by allowing it to ascend.

As to the size of hot-house fire-places, the door of the furnace may be from ten inches to one foot square; the fuel chamber, from two to four feet long, from eighteen inches to two feet wide, and of the same dimensions as to height. Every thing depends on the kind of fuel to be used. For Newcastle coal, a chamber two feet long, eighteen inches broad, and eighteen inches high, will answer as well as one of double the size, where smoky Welch or Lancashire coal is to be used.

In the modes of constructing flues for heating houses for keeping plants there is considerable variety.

The sides of common flues are commonly built of bricks placed on edge, and the top covered by tiles, either of the full

width of the flue, outside measure, or one inch narrower, and the angles filled up with mortar. Where a stone that will endure fire heat without cracking, is found to be not more expensive than tiles, it is generally reckoned by far preferable, as offering fewer joints for the escape of the smoke. Such stones are sometimes hollowed on the surface, in order to hold water for the benefit of plants in pots, or for steaming the house.

Of other improvements which have been proposed, that of making them broad and deep, agreeably to the Dutch practice, has been recommended by Stevenson; that of making them narrow and deep, agreeably to the practice in Russia, is recommended by Oldacre; and that of using thin bricks with thick edges, by S. Gowen, takes up less room than any other brick flue, the covers and the common bricks being quite thin, the base requisite for building them on one another being obtained by the thickness of their edges, which is equal to that of common bricks.

Can-flues, long since used by the Dutch, imbedded in sand, and for the last fifty years, occasionally, in England, consist of earthen pipes straight or rounded at the ends for returns, and joined together by cement, placed on bricks. They are rapidly heated, and as soon cooled. None of the heat, however, which passes through them, can be said to be absorbed and lost in the mass of enclosing matter. They are, however, only adapted for moderate fires; but, judiciously chosen, may frequently be more suitable and profitable than common flues; as, for example, where there are only slight fires wanted occasionally, or where there is a regular system of watching the fires, in which case the temperature can be regulated with sufficient certainty.

Cast iron flues have also been recommended on account of their durability, but unless they were to be imbedded in sand, or masonry, they are liable, in an extreme degree, to the same objections as can-flues.

The size of flues is seldom less than nine inches by fourteen or eighteen inches, inside measure, which suits a furnace for good coal, whose floor or chamber is two feet long, eighteen inches wide, and eighteen inches high.

The furnaces from whence the flues proceed are generally placed behind the back wall, as being unsightly objects; but, in point of utility, the best situation is at the end of the front wall, so as it may enter the house, and proceed a considerable length without making an angle. Utility, however, is generally sacrificed to beauty in this department of gardening.

The direction of flues, in general, is round the house, commencing always within a short distance of the parapet, and after making the course of three sides, that is, of the end at which the fire enters, of the front, and of the opposite end, it returns,

in narrow houses, near to or in the back wall, or, in wide houses, up the middle, forming a path; and in others, immediately over or along side of the first course. In all narrow houses this last is the best mode.

The power of flues depends so much on their construction, the kind of fuel, the roof, mode of glazing, &c. that very little can be affirmed with any degree of certainty on this subject. three thousand cubic feet of air are, in general, enough for one fire to command in stoves or forcing-houses; and five thousand in lean-to green-houses. In houses with glass on all sides, two thousand cubic feet are enough in stoves, and three thousand cubic feet for green-houses. The safest side on which to err, is rather to attach too little than too much extent to each fire; as excessive fires generally force through the flues some smoke or noisome vapours; and, besides, produce too much heat at that part of the house where the flue enters.

Sometimes the flues are carried under ground to some distance from the hot-house, and the chimney carried up in a group of trees, or otherwise concealed. This practice is most suitable to detached buildings, formed of glass on all sides.

When fuel that yields no soot is used, then, instead of straight lined flues, a cellular wall, as hereafter described in treating of steam heat, may be used.

As soon as smoke flues attain such a length that the temperature of the heated air is less than 212 degrees Fahrenheit, cast-iron pipes might be used with advantage, because they would afford more heat, and at the part of the flue most distant from the fire, where heat is most required.

By the usual method of employing a slow conductor for the whole length of the flue, a part of the heat is lost, and the smoke escapes at an elevated temperature. A high chimney will also be found to make a considerable difference in the effect that can be gained from smoke-flues; because a rather forcible draught is required to make the smoke circulate through much extent of horizontal flues.

The most serious evil in smoke-flues is the great number of chimneys requisite; though this might be obviated by a chimney of considerable height being built where it could most conveniently be seated, and into which the flues of the separate furnaces might be conducted either under or above ground.

### *Steam Heat.*

Steam is a vehicle for conveying heat, which, when employed at a low pressure, will never give to the vessel containing it a greater heat than that of boiling water, or 212 degrees; and when the surface is of a proper material, the heat produces no

sensible effect on the air, can be conducted to any part of a building with the utmost facility, and is perfectly safe.

One important advantage is attained by a steam apparatus, which distinguishes it from every other method of distributing heat, which is, that it can be extended to a very great distance from the boiler in every direction. We can cause it to ascend, descend, or move horizontally with equal facility; the loss of heat is inconsiderable in conveying it to a distant point; hence, one single fire is sufficient for an immense establishment, and this one may be placed where the smoke of a chimney is least offensive, and its appearance least objectionable. The distance from the boiler to the end of the most distant house, at Messrs. Loddige's of Hackney, is about eight hundred feet, and it does not appear to be carried to the greatest extent.

But, wherever steam is employed, it should be under the direction of a person competent and willing to attend to it, and having no other business to take off his attention. For, though in such hands it is perfectly safe, and easily managed, it is by far too complicated to be trusted in the hands of common servants, who are occasionally employed in other places. The apparatus must be kept in order, and though only a small degree of attention be necessary for that purpose, it does not admit of neglect. The supply of fuel, also, requires more frequent renewal than in common furnaces.

"It is," as Mr. Tredgold observes, "very commonly asserted, that steam heat is more economical than that of smoke-flues; how the comparison has been made is not known; but he must be a novice in the science of heat, that cannot produce nearly the same effect by the one as by the other, all other circumstances being the same. In either method it is easy to mismanage things in such a manner, that no more than half the heat will be effective in warming the intended space; and by selecting cases for comparison, you may make either appear to be the best method, as far as regards economy of heat. Where a proper attention can be given, steam is preferable; but in other cases, flues will be found to answer better."

In ordinary dwelling-houses, it does not appear to be desirable to employ steam-heat alone; but it may always, in large houses, be made an auxiliary mode of procuring warmth and assisting ventilation.

A large room is seldom comfortably warmed by open fires; and halls, staircases, and passages, cannot be warmed by them without a great waste of fuel. But the most advantageous method seems to be, to unite the two principles of warming; that is, in the rooms to use the radiant heat of an open fire, and also supply the rooms with air partially warmed; while the passages, halls, staircases, and workshops, are warmed by proper steam-vessels.

The quantity of heat required will indeed be greater, as the quantity of glass is greater; but, from motives of economy, the invigorating influence of an abundant supply of light ought never

to be excluded, particularly in schools and work-rooms; for the more we exclude light and air, the more pale and languid we shall render the persons who inhabit them. By making the windows double, the loss of heat may be reduced to less than one-third, without sensibly lessening the quantity of light.

The quantity of steam has been hitherto proportioned to the cubic foot of space to be heated: a superficial foot of steam-pipe, it is said by Mr. Buchanan, will heat about two hundred cubic feet of space, or a cubic foot of boiler two thousand cubic feet of space.

These proportions are given for cotton mills, but they are perfectly useless in any instance where a different degree of ventilation is necessary, as in hospitals, or where a greater proportion of window is necessary, as in houses for growing plants.

There are two causes of loss of heat in buildings—the cooling effect of the external air against the windows, or other external surfaces of the building; and the quantity conveyed away by the impure air, which must be removed by ventilation, the outlets by crevices, and other openings. These will always be measured by the quantity of air that is to be heated to the temperature of the room, from that of the external air; and, therefore, the fuel or the surface of steam-vessel that will be sufficient to heat that quantity of air, will sustain the room at the proposed temperature.

Hence the quantity of surface of steam-pipe that will maintain a room at a given temperature, is easily calculated, if the degree of ventilation, and the loss of heat, be previously estimated.

To make this calculation in the proper manner, the temperature of the external air, or of the air that supplies the ventilation, is to be known at the extreme case of cold, which, for the day, may be taken at 30 degrees; but for night may generally be assumed at once, to be at zero of Fahrenheit's thermometer, as the cold is seldom more intense in this climate. The temperature at which it is proposed to maintain the room, or place to be heated, at the same season of cold, is also to be settled, and the quantity of air by the minute, which must be raised from the temperature of the external air to that of the room, in order to supply the loss of heat by the glass of the windows, the crevices around the windows and doors, and the ventilation required for the number of people in the room.

Each person in the room may be estimated to require a supply of four cubic feet of air, but in sick rooms six feet by the minute, each superficial foot of glass to cool a cubic foot and a half, and the crevices around each moderate-sized door or window, opening to the external atmosphere, to cool eleven cubic feet in the same space of time.

In houses for plants the crevices of the panes may be estimated to cool as many cubic feet of air by the minute as are equal to the length of the house in feet multiplied by half the greatest height, independent of the cooling action of the doors and sliders.

These points being ascertained, Mr. Tredgold gives this rule to find the necessary surface of steam-pipe: multiply each cubic foot of air to be heated by the minute, by the difference between the temperature the room is to be kept at and that of the average external air, in degrees of Fahrenheit's thermometer, and divide the product by the difference, previously multiplied by 2.1, between 200 and the temperature of the room. The quotient is the quantity of surface of cast-iron steam pipes that is required.

Mr. Tredgold, in his Principles, has shown that a bushel of Newcastle coals by the hour, will supply heat to 1820 feet of surface of pipe in a room at 60°.

| | | |
|---|---|---|
| 2100 ditto | . . . . . | at 80° |
| 2500 ditto | . . . . . | at 100° |

If the condensed water cannot be returned to the boiler, about one-twelfth of the heat will be lost; and consequently, these quantities of surface must be reduced by one twelfth.

In addition, there will be required as much fuel as will supply the waste of heat at the boiler, and if no means are employed to prevent loss of heat at its surface, the loss of heat at the boiler will often be equal to the effect of the steam-pipes it supplies, and in small boilers the proportion of this loss will be greatest.

On a gross calculation, it will require a bushel of coals, every winter, for each six cubic feet of air which is to be heated by the minute.

Another consideration is, to know the quantity of water that will be condensed in a given time, because then, where the condensed water is not, or cannot, be returned to the boiler, the supply of water that will be required can be estimated. In a room at 60°, 182 square feet of cast-iron steam-pipe will condense a cubic foot of water in an hour; at 80° it will require 210 feet; and at 100°, 252 feet to condense the same quantity.

### *Feeding Apparatus for Steam-Boilers.*

The apparatus required to supply steam for heating rooms and plant-houses, is perfectly analogous to that used in the general chemical laboratory already described; but it is usually made on a larger scale; and should any part of the top of the boiler be exposed to the open air, it is made double, and the interstices carefully filled with stifled charcoal ground to powder.

As these large boilers require a considerable supply of water, it is usually, and almost absolutely necessary, to furnish the steam-boilers used for this purpose with an apparatus by which they may supply themselves with water from a cistern, which must be raised so much above the level of the water as may counterbalance the expansive force of the steam, according to the rules laid down in page 78, namely, two feet .1 in height, for each pound of pressure the steam is worked at above the pressure of the atmosphere.

The most usual kind of feed-pipe is shown at *a*, *b*, fig. 54. The lower part of this pipe is turned at the end to prevent steam rising through it. Where it passes through the top of the boiler, it is made steam tight, and fixed in a vertical position. The top of the pipe terminates in a small cistern head, *c*, which is kept supplied with water from a large cistern, *d*; and at the bottom of the small cistern, *c*, there is a conical valve opening upwards, connected by a chain to a lever, *e*, which turns on a centre with a wire, *f*, attached to the opposite end. This wire passes through an air-tight stuffing box to a flat stone in the boiler, which is so balanced by a weight, *g*, on the opposite end of the lever, as to float on the surface of the water.

Its action is performed in this manner:—When part of the water is evaporated from the boiler, the stone-float descends with the water's surface, and consequently raises the conical valve; now the small cistern-head, *c*, being kept constantly full of water, by a pipe from the cistern, *d*, as soon as the valve is raised, water enters the boiler, and when it is filled to the proper level, it raises the stone-float, and shuts the valve, till a repetition of the operation becomes necessary.

The principal circumstance to be attended to in the construction of this apparatus is to make the height of the water in the small cistern sufficient to balance the strength of the steam. For if this height be too small, the water in the boiler will be forced up the feed-pipe by the pressure of the steam, and be driven out at the valve. Therefore, when this height is correctly arranged for the greatest strength of steam it is proposed to employ, which is generally two pounds and a half to the square inch, this pipe answered the purpose of a safety valve; and in boilers for steam apparatus, where the stop-cock of the steam-pipe is made so that it cannot be perfectly closed, no other safety valve is necessary. For the steam will always flow through the feed-pipe as soon as the pressure exceeds the head of water in the cistern; with this view the part of the pipe, *a*, *b*, may be made larger, and also the valve. And a small open pipe, *h*, will allow air to enter if a vacuum be formed, or water to escape whenever the pressure is too great.

There is a more simple kind of feeding apparatus, in which the depression of the stone-float opens a cock in the pipe from the cistern; the height of the cistern being regulated as for the preceding method.

Fig. 55 represents this method: *a*, is the pipe for supplying the boiler with water; *b*, a wire by which the stone-float on the surface of the water moves a cock, *c*, in the pipe, *a*, to admit a fresh supply of water when necessary. *D*,* is a small pipe for admitting air to the boiler in the case of a vacuum being formed, or to allow steam to escape if it become too strong.

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* This pipe is entirely unnecessary, where the stop-cock is used instead of the puppet-valve, fig. 54, as the formation of a vacuum in the pipe below the stop-cock, can in no way operate to prevent the opening of the cock.—Am. Ed.

Fig. 53.

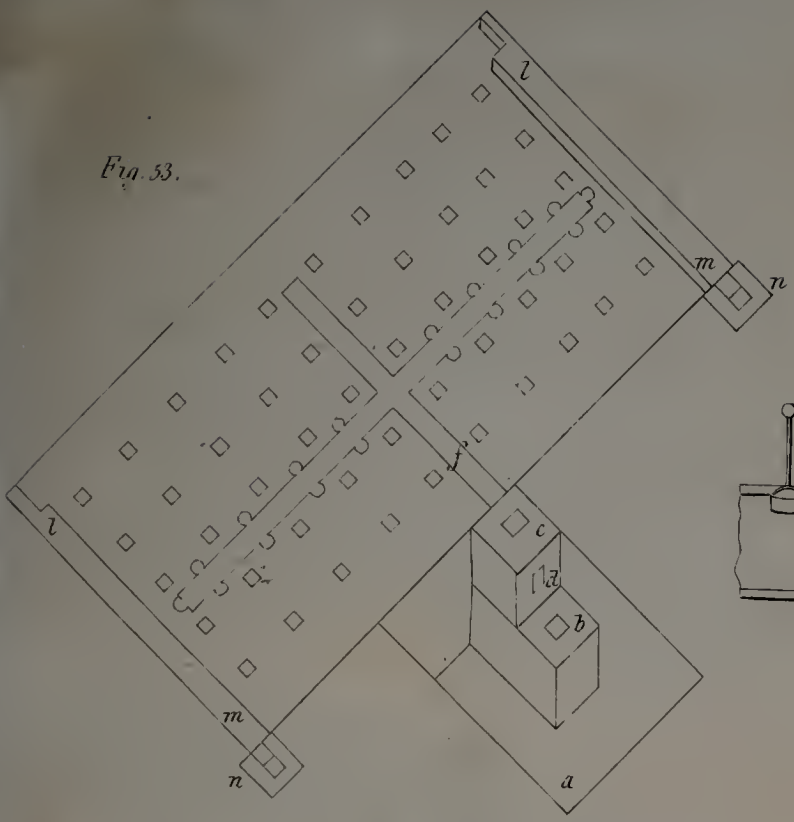



Fig. 56.

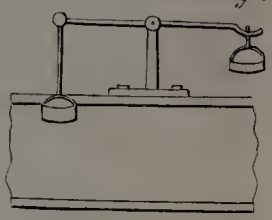


Fig. 54.

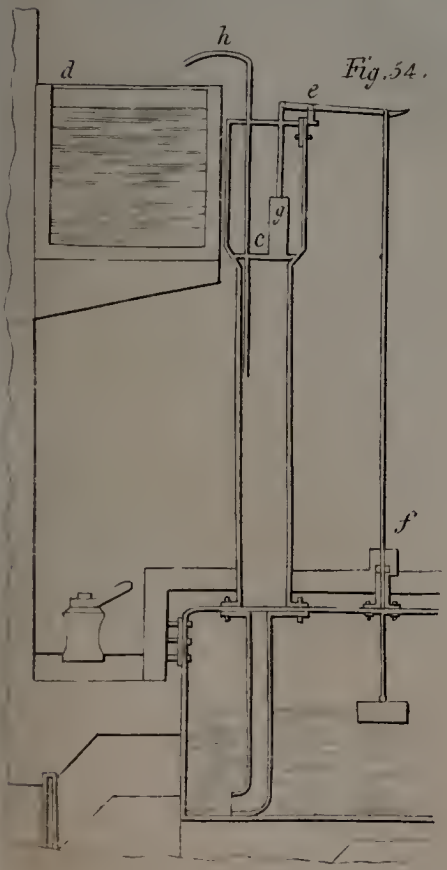
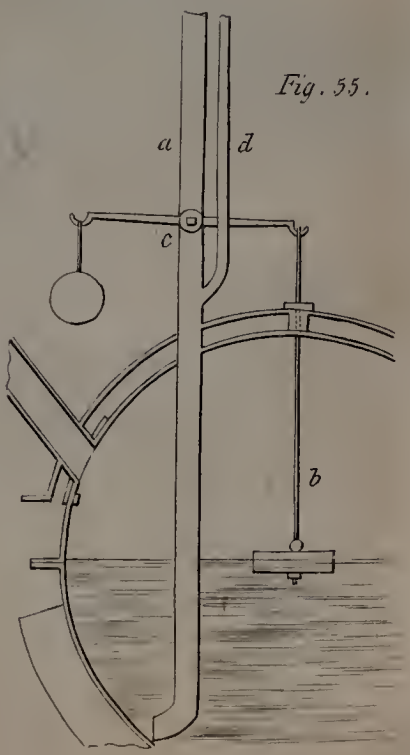



Fig. 55.



### *Steam-Pipes.*

In respect to the materials for pipes and vessels, it is most usual to employ cast-iron for steam-pipes and vessels; and it is justly esteemed preferable to all other metals for this purpose, because it does not, by being heated, exhale any thing injurious. It may be formed of any shape that is most convenient, and is strong and durable.

Tinned iron is less expensive than cast-iron; but it is also less durable; besides, vessels and pipes formed of this material must be provided with valves to prevent them collapsing.*

Fig. 56, shows the form of the valves which open inwards, and in which the valve is balanced by a weight at the opposite end of the lever.

Copper is objectionable, because it exhales a peculiar odour when heated, which is neither agreeable nor healthy. But in drying-rooms it will be required, because iron would injure the linen, &c.

In copper pipes it will also be necessary to place valves to prevent them collapsing.

Lead is wholly unfit for pipes to convey steam, because pipes of lead become longer every time they are heated, and ultimately crack.

For small pipes, it will be necessary to use wrought-iron ones, such as are made for gas-pipes.

In respect to the space for steam, when the supply is to be continual, if it be too large, the distributing apparatus will be long in filling; if it be too small, the steam will flow with difficulty.

The diameter of pipes should never exceed six inches, nor ought they to be less than three inches where the quantity is considerable. When the pipes would exceed six inches, to gain the necessary quantity of surface, then it would be better to have two pipes; and with a very little extra trouble it can be arranged so that both the pipes, or only one of them, may be heated. But where the condensed water is to collect in the pipes, and to supply heat when the steam has ceased to flow, large pipes will be best. Those of cast-iron will be of sufficient strength when cast as thin as they can be formed, so as to be perfect. This can be done with somewhat less than three-eighths of an inch of thickness.

In elegant rooms, pipes cannot be employed with propriety unless concealed; and therefore other forms of vessels must be

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* A still greater objection to the use of tinned iron is, that it would require from 6 to 8 times the extent of surface to produce a given effect, when compared with cast iron; that is, on the supposition, that the tinned iron has the polish of the article when new, and the iron its usual dark and dull surface.—Am. Ed.

used. The cavity between two hollow cylinders or prisms, the one inserted within the other, being filled with steam, it will offer a considerable extent of surface without occupying much space, and may be made to appear as a pedestal for a bust. Even ornamental columns, pillars, vases, and the like, may be adapted to contain steam.

It is, however, necessary to provide against the expansion which all bodies suffer when they are heated. This expansion differs in every metal;—one-eighth of an inch for every ten feet in length of cast-iron pipe must be allowed for its expansion; one-eighth of an inch should be allowed for expansion of tough iron pipes, for every eight feet in length; two-tenths of an inch should be allowed for the expansion of copper in every ten feet in length.

The allowance for the expansion of lead approaches nearly to seven-twentieths of an inch for each ten feet in length. But in lead pipes, employed to return the condensed water to the boiler, one-fifth of an inch for every ten feet will be sufficient.

That pipes may be at liberty to move freely as they expand, they should be supported on rollers.

In heating new buildings by steam, vertical pipes have been employed; and, with an idea of economy, these pipes have been made to answer as principal supports for the buildings; but the expansion of the pipes is a great objection to this mode, and it is a considerable advantage, in all cases, to have the heating apparatus distinct from the fixed parts of a building, so that it may be renewed, altered, or repaired, without injury to the substantial parts of the structure: this, with the consideration abovementioned, more than compensate for any extra room required to have the apparatus distinct.

The usual and the best mode of joining pipes, &c. is by flanches. In the joint should be inserted a flat plait of slightly twisted hemp yarn, which has been previously saturated with stiff white lead paint. If a little red lead be mixed with the white lead paint, it will dry sooner and become considerably harder. And flannel, or mill-board, may be used in the place of hemp.

Some use iron cement for the joints; but where white lead and hemp or mill-board can be used with propriety, it is preferable.

Wrought-iron pipes may be joined by making each of the lengths that are to be put together to screw into a piece of pipe of larger diameter. They may also be screwed into cast-iron pipes, cylinders, &c. so as to serve as branch-pipes, connecting-pipes, and the like.

Where, in consequence of turns and angles, no other mode of avoiding the effect of expansion will apply, the pipes may be connected, by a short length of smaller pipe, to slide in a stuffing-box in one of the pipes.

In every part of the distributing apparatus it is necessary to prevent any considerable quantity of water collecting, as it condenses the steam so rapidly as to endanger the boiler and pipes being forced together by the pressure of the atmosphere, should they not be firm enough to resist the pressure.

When it is possible to have the boiler at a lower level than the pipes and other steam vessels, it is best to return the water of the condensed steam into the boiler again, because it not only saves fuel, but also requires a smaller supply of fresh water; an object worthy of attention where water is scarce.

In conducting steam heat to the place where it is to be applied to some useful purpose, it must be prevented from being lost in the passage.

If a steam pipe be simply placed within another pipe of larger diameter, and kept in the middle by slow conductors of heat, it will lose only a small portion of heat.

For conveying steam-pipes to a considerable distance under ground, in a dry soil, a drain may be formed, and fitted at the bottom with brick-bats, small-stones, or the like open materials; and the pipe laid in so as to be surrounded, on every side, with about three inches in thickness of dry ashes, covered with a coat of well-mixed clay over the top, to keep off the water, and also with such a depth of earth as may be necessary to prevent it being disturbed.

### *Condensed Water-Pipes.*

The water ought to be returned to the boiler in all cases where we do not retain the whole of it in the pipes, to afford a supply of heat after the fire is burnt out. The most simple and obvious plan of doing this is to give the pipes a descent to the boiler, where it can be placed at sufficient depth for that purpose.

The best plan is for the steam-pipes to proceed in the nearest course to the highest point where steam is required, and then descend to the lowest, from which a small condensed water-pipe may return the water to the boiler.

This condensed water-pipe ought to be surrounded with slow conductors of heat, so that as little as possible may escape. When the boiler cannot be placed at a sufficient depth below the lowest place where heat is required; the water can, in some cases, by the power of steam to support a certain column of water, be returned to a higher level in this manner.

In fig. 57, *a*, shows the cistern to which it is to be returned; and, *b*, the lowest part of the steam-pipe; *c*, *d*, is a pipe from the steam-pipe to the cistern, with a valve at *c*, to prevent the water forced into this pipe, by the pressure of steam in the steam-pipe, from returning. The arch, *d*, must be above the level of the water in the cistern, and the height, from the end of the steam-pipe to this arch, not more than two feet and a quarter for each pound of pressure upon a square inch.

Where sufficient room can be obtained, the most certain apparatus for taking off the water of condensation, is the inverted syphon, which has been long used for that purpose.

Fig. 58, represents a syphon of this kind; in which *a*, is the lowest point of the steam-pipe, and of course any water that collects in the pipe will flow into the syphon, *b*, *c*, *d*, and run out at *c*, either to waste or into a hot-water cistern. The depth, *a*, *b*, should not be less than is equivalent to the force of the steam in the pipes; consequently, if the steam should be worked at four pounds to the square inch, the column of water, *b*, *c*, should not be less than ten feet, and even, with this pressure, there will be considerable oscillations, unless a valve be placed at some point in the branch, *d*. When the legs are both filled with water and at rest, this valve should open, and be constructed so as to close whenever the water has a tendency to flow back into the pipe.

The syphon should be large enough to take away all the condensed water with ease; but it should not be too large, because there will be a loss of heat in the leg, *d*, from its being filled with steam; and in all cases, the syphon should be carefully protected from freezing.

When sufficient depth cannot be got for a syphon, a steam-trap or valve, to open by a float-ball, is employed.

Fig. 59, represents this apparatus; *a*, is the lowest point of the steam-pipes, to which a cast iron box, *b*, *c*, is attached; as also a blow-pipe, *d*, to let out the air which the steam drives before it, when it is first let on. The box, *b*, *c*, has a pipe, *e*, at the bottom to let out the condensed water flowing into the box from the steam-pipes, and either let it run to waste, or collect it for other purposes. In the box, *b*, *c*, is a conical valve, *f*, which stops the entrance of the condensed-water pipe, *e*; to this valve is affixed a hollow copper ball, *g*, of sufficient size to float it, and which is kept in a proper position by the wire, *h*, running through a stay in the upper part of the box. When, therefore, steam is condensed, the square box will fill with water, which will float the hollow cylinder, consequently the water will escape, and run by the pipe, *e*, into the drain at all times, when the quantity in the box is greater than is required to float the cylinder; when there is less than will float it, the valve of course closes.

## *Cellular Hot Walls.*

To save the expense of cast iron pipes, the gardeners have invented the cellular wall, which is built with cells communicating with each other from the surface of the ground to the coping. The main steam-pipe is introduced in the lower part, and conducted along the foundation, and the vapour allowed to ascend through the cells to the top. It condenses in the masonry, and heats uniformly the whole material of the wall. If the height does not exceed ten or twelve feet, these walls may be formed of bricks set on edge, each course or layer consisting of alternate series, of two bricks set edgeways and one set across, forming a thickness of nine inches, and a series of cells nine inches in the length of wall, by three inches broad. The second course being laid in the same way, but the bricks alternating or breaking joint with the first, the cells will of course communicate with the others.

The advantages of this wall are obviously considerable in the

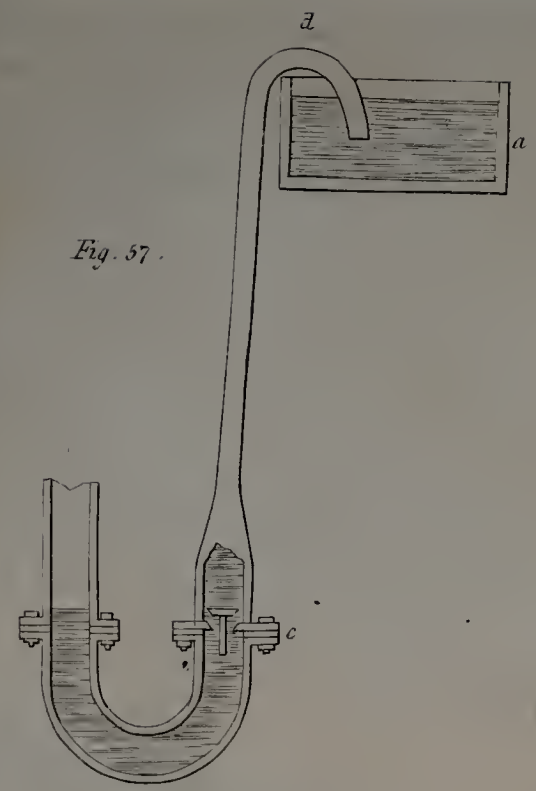



Fig. 57.

Fig. 58.

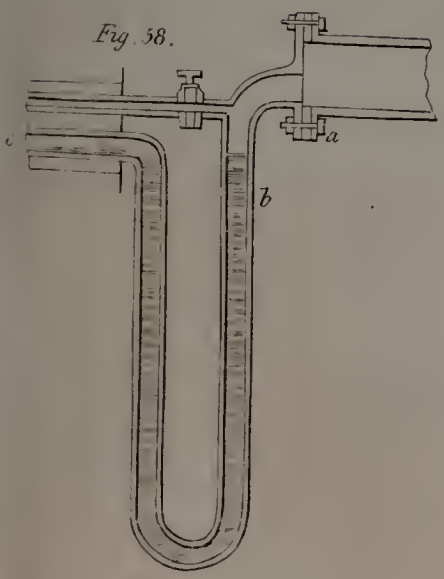
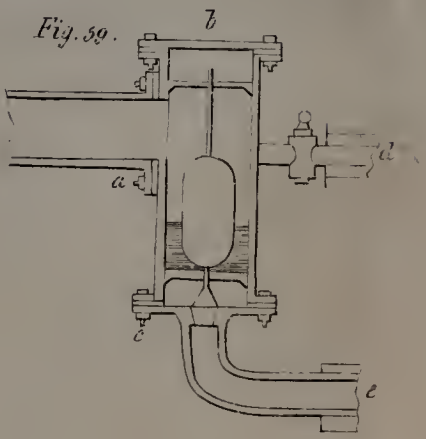



Fig. 59.



saving of material, and in the simple and efficacious mode of heating; but the bricks must be of the best quality, and the mortar such as will not be injured by alternate drought and moisture. For this purpose Stourbridge or London bricks will be found the best, and either common mortar, mixed with powdered ferruginous stones, pozzolana or decomposed lava, tarras or decomposed basalt, or pure lime and clean coarse sand used in a recent state.

This wall has been tried in several places and found to succeed perfectly as a hot wall, and at ten feet high to be sufficiently strong as a common garden wall, with a saving of one brick in three. The same idea may be advantageously applied to flues for heating hot-houses by steam, and for other purposes.

There are two purposes for which steam heat is thought to be particularly useful: first, the maintaining of rooms in a more equal temperature than that afforded by our common open fires, without having recourse to close stoves for that purpose, as there exists an absurd prejudice against these stoves in the public mind; and, therefore, this operose method is chosen in preference to the more simple method which they offer of effecting that purpose.

Secondly, the drying of linen, cotton, or woollen cloth, in the several operations of bleaching and dyeing.

### *Madeira Rooms, or Rooms of equal Temperature.*

The numerous and distressing cases of consumption in our climate, have directed the attention of medical men to the means of procuring for their patients the advantages which are said to be derived from a removal to warmer situations, by keeping up an equal temperature in their chambers.

To bring together and mix a great many persons, labouring under the same disease, must too often be exceedingly hurtful; and to provide distinct apartments for each, would be attended with too much expense to be practicable; and when people are languishing under disease, what place is like home, sweet home!

The room should first be made as air-tight as possible, by pasting strips of canvas and paper over all the openings; and a double door may be added: the additional door being made as small as will answer the purpose. The chimney must also be closed up, and the window have double sashes.

The next object should be to admit as much warmed air as will ventilate the room, and allow the other to escape at the ceiling. The warm air admitted should be five or six degrees below the temperature the room is kept at, as the rest of the warming ought to be effected within the room. The quantity of air to be warmed for ventilation, for an ordinary-sized room,

will be about twelve cubic feet by the minute, and if the room is to be kept at sixty-two degrees, the air should be heated to fifty-six degrees before it enters. This may easily be effected by means of a boiler placed within the hob of a kitchen fire, or a small portable boiler of the kind used for steam-baths, with tin-plate pipes.

A three-gallon boiler, with an equal space for steam, will be sufficient. The pipes should be so placed that the condensed water may return to the boiler.

The air to be warmed should be brought from the external air to pass through the wall into an iron or tin box, containing the steam-pipes: the air being warmed, it is made to rise through a pipe at the top of the air-box into the room. In order to prevent the loss of as little heat as possible, the air-box ought to be enclosed in a wooden case.

A pipe of the same diameter will be required for the escape of air at the ceiling. The size of both these pipes should be about three inches and a half diameter; and they should each be provided with a register to regulate them.

The quantity of steam-pipe to heat the air-box to fifty-six degrees, when the external air is at thirty degrees, would be one superficial foot, if they were of cast iron; but it will require nearly two superficial feet of tin-plate to give the same quantity of heat, hence the surface of the pipes should be two feet, or they may be four inches diameter, and one foot long. The steam should be brought by a small pipe from the boiler into the upper pipe of the air-box, and from thence into the lower one, and return, when condensed to water, by a small pipe to the boiler.

About four feet of surface of cast iron pipe or vessel, or eight feet of surface of tin-plate, will supply sufficient heat to keep a moderate-sized room at sixty-two degrees.

An indexed cock should be placed in the pipe, so that the supply of steam may be regulated by any person in the room.

[If we admit the correctness of the remark of Mr. Tredgold, just quoted, in relation to steam heat and smoke flues, "that he must be a novice in the science of heat, who cannot produce nearly the same effect by the one as by the other, all other circumstances being the same," of which there is some reason to doubt; there is but a single argument in favour of the employment of the former, and that is its absolute safety. This is certainly a very weighty consideration, and particularly in cotton factories, and other buildings peculiarly exposed, from the nature of their contents, to fire. But the Belper, or Wakefield stove, shortly to be described, approaches so near to this desirable point that the risk in its employment is extremely small. One of the principal objections to the use of steam for these pur-

poses is the great expense of the apparatus compared with that of the hot air flues. I am not prepared to state with precision what the difference in the expense of the apparatus is for warming in these two ways, but do not hesitate to say that at the present price of iron castings and boilers in New England, the arrangements for steam would exceed those for the hot air stoves by at least, four or five times. Nor is this great difference in expense compensated by greater permanency in the former apparatus when once obtained; on the contrary the wear and tear must, I think, be much greater;—cast iron pipes will, indeed, last a long time, but no species of apparatus is worked at greater expense for repairs than large steam boilers.

The want of ventilation is a still more serious objection to this mode of heating; those, who have experienced the confined and suffocating air of a cotton mill heated by steam and the fresh summer-like atmosphere of one warmed on the hot air principle, cannot hesitate for a moment to decide in favour of the latter on the score of healthiness, comfort and cleanliness. It may, it is true, be said, that, although the arrangements for steam do not furnish the necessary ventilation, they do not preclude the adoption of other means of effecting that object. But the truth is, there is no means of ventilating an apartment so simple, and so effectual, as by connecting the two operations inseparably together. The importance of a pure atmosphere is seldom sufficiently appreciated by the generality of people to ensure that attention to the subject, which it really demands; and accordingly we find that in large establishments, as well as in private dwellings, where the necessary means are provided by apertures to be opened and shut at the pleasure of the occupant, and in accordance with his view of the propriety of the operations, the business is almost sure to be neglected. The great mass of mankind are the creatures of sense rather than of reflection; remote and contingent evils lose their relative importance when compared with those, which appeal directly to the senses. The slow and gradual, but certain and pernicious, influence of an insalubrious atmosphere is little heeded in comparison with the more immediate effects of heat and cold. It should therefore be the aim of the architect to combine the two operations of warming and ventilating, which cannot, or at least has not, been effected where steam is employed. The writer is led to these reflections from having often contrasted the pallid and sickly countenances of the tenants of the Manchester factories and work-shops with the comparatively fresh and healthy complexions of similar classes in New England; and this difference is the more remarkable since the general complexion of the inhabitants of England, even of the

humblest of the labouring classes, is more florid and healthful in appearance, than the people of our northern and eastern states: these results are doubtless in part owing to the operation of other causes, such as differences in food, clothing, &c., but no one circumstance appears to him to have contributed more to depress the physical character of the British manufacturing operatives than the almost universal practice of warming their large mills and work-shops by steam.

It might be supposed that the ventilation proposed in connexion with the hot air stoves, would only be effectual during the season of using fire, but it will be seen that this apparatus is equally effectual for this purpose where no fire is used.]

### *Steam Drying-Rooms.*

Steam-heat has been found less injurious to cloths of all kinds than any other method; for it neither communicates a harsh feel, nor impairs the lustre nor colour of the brightest dyes.

[This notion was for a long time entertained by calico printers and bleachers, but is, I believe, now generally discarded, except by the common workmen. The writer can affirm from the most ample experience that artificial heat produced in any other way, provided the atmosphere is preserved equally free from smoke and dust, will answer all the valuable purposes of steam-heat. The harsh *feel* sometimes imparted to cloth in drying by stove heat is the effect only of too high a temperature. The adoption of steam, or stove heat must be determined by considerations of expense altogether.]

It may be applied to drying muslins, calicoes, linens, yarns, or paper, and to laundries in domestic economy.

The process consists in confining the heat to a closet of sufficient magnitude to receive the goods to be dried, and so contrived, that the workmen can change them with facility, without being exposed, in any material degree, to the intense heat and moisture of a drying-room.

Besides the inestimable advantage of being more healthy, this mode of drying is also more economical; because we can employ a temperature, and a current of air, which it is difficult to render at all effective in any other mode.

It will be obvious that dry air will act most powerfully; and, as the external air is frequently very damp, whenever that is the case, the manager of the drying-stove should admit air more sparingly, and work at a higher temperature, otherwise there will be a waste of fuel.

The atmometer of professor Leslie would be a useful instrument in a drying-room, as it measures the quantity of moisture exhaled by a humid surface in a given time. For though its

indications are not to be relied on for many meteorological inquiries, it is sufficient for the purpose here proposed.

The walls of the drying-closet should be of such a nature that they may absorb only a small quantity of moisture; and for this purpose they may be lined with glazed tiles.

Small drying-closets for private families, may be made entirely of wood; the effect of warping must be prevented by employing narrow strips, ploughed and tongued together, and fastened with copper nails, or wooden pins, as iron cannot be employed, on account of the rust that would be formed.

The frames on which the cloth is hung, should have wheels to each, in order that they may be easily drawn out. Frames suspended as the sashes of a window, may be often adopted. The space through which they are drawn out, or moved in, being provided with doors to shut close. There should be at least one spare frame, so that the drying-room may be kept constantly full.

The air should be heated by a portion of the steam-pipes, before it enters the real drying-room, or closet; and there should also be more pipes between the frames, for elevating the temperature of the goods. The outlets for the air at the top of the drying-closet must be provided with a regulator. There must also be another register to regulate the admission of cold air to the air-chamber.

The weight of water which is absorbed by cloths, is very different.

| | Weight dry. | Weight wet. | Weight of water absorbed. |
|---|---|---|---|
| Flannel | 1 pound | 3 pounds | 2 pounds |
| Calico | 1 pound | $2\frac{1}{8}$ | $1\frac{1}{8}$ |
| Linen | 1 pound | $1\frac{3}{4}$ | $0\frac{3}{4}$ |

Mr. Tredgold says that the most economical rate of drying will be, when the quantity of moisture evaporated is eight parts in one hundred, of the whole quantity the goods contain, in one-thirtieth of the time it is intended each piece shall remain in the drying-room. The heat which may be taken as the most desirable to work at in practice, is ninety degrees. In goods of a thick texture, a longer time and a lower temperature must be employed.

In respect to drying cloth of any kind, Mr. Tredgold, from his experiments, estimates that it will require thirty cubic feet of warm air, to carry off the moisture of each square yard of cotton cloth, that the quantity of steam-pipe required for a piece of twenty-five yards is 138 superficial feet of copper pipe, disposed between the frames on which the goods are suspended. To heat the 750 cubic feet, that is required of air to 90°, supposing the external air at 40°, will require 132 feet more.

These last pipes are to be placed in an air chamber, under the drying-room, so as to heat the air to 90° before it comes in contact with the goods; and will be best made of cast iron.

As to the time this quantity of steam-pipe will take to produce a given effect, it may be stated, in general, that it will require about four minutes to steam away a pound of water from twenty-five yards of calico. To dry in double this time will require only half the quantity of surface of steam-pipe; and so of any other proportion.

For domestic purposes about one-third of this proportion of steam-pipe will be sufficient; that is, forty-five feet in the air chamber, and as much in the drying closet, for each twenty-five yards of cloth, or an equivalent surface of other matter.

The area of the pipe to convey away the steam may be proportioned by considering the rules which have been given for ascertaining the draught of chimneys. If Mr. Tredgold's opinion is taken on this disputed subject, then if the height of the pipe for carrying off the steam, measured from the centre of the heated chamber to the opening where the steam and hot air go out into the atmosphere, be twenty-five feet, the area of the horizontal section of the pipe must, for 270 square feet of surface of steam-pipe, be one square foot, and rather more than a-half.

All the passages for air will require to have about the same area.

A closet to dry linen for a family ought to have two horses, each of which should contain a sufficient quantity of linen, or other cloth, to require about an hour to dry them; when the first is about half dry, which it will be in about twenty minutes, another quantity should be put in upon the other horse. By this mode of changing them alternately there will be a considerable saving of fuel as well as of time.

For domestic purposes there will be quite as little expense in fitting up an apparatus of this kind as the most common in use. One of the boilers in the wash-house will answer as a steam-boiler, without rendering it the less fit for other purposes.

[The best and cheapest method of drying cloth in calico printing and bleacheries is in the open air. White goods never look so well when dried by artificial heat. More room is required in the former case; but the buildings for this purpose may be of the cheapest construction. In large works, however, and particularly in the winter season, the occasional use of artificial heat is often convenient, and sometimes indispensable, to despatch in business. When this is recurred to, I have already observed, that the employment of steam or stove heat may be resolved into a question of economy merely. On this

question I have also offered some remarks at the conclusion of the article "*steam heat.*" If a stove heat be employed, which I should certainly advise on the score of economy, I should recommend a stoving room of the following construction:—The building to be of brick, thirty feet wide, twenty-eight feet high, and of a length to correspond with the extent of the work to be performed: the roof of the ordinary construction, and ventilated at the top by apertures equal to one foot square for every twenty feet length of the building. The floor of the building, which is of earth, to be traversed lengthwise by two parallel horizontal flues, two and a-half feet wide, and six inches in depth; the sides and bottom of the flues to be of brick, and the top of thick cast iron plates, connected by flanges and bolts; each of these flues to be terminated by a fire-place at one end, and a chimney at the other, but in the reverse order, so that there be a chimney and fire-place at each end of the building: the fire-places to be fed on the outside: to prevent loss of heat downwards the flues should rest on shoal arches, or on bricks set edgewise, so that the air may circulate underneath. This arrangement, with two straight flues, is much preferable to the common one of having but one flue in the form of the letter U, with the fire-place and chimney at the same end of the room, on account of the liability of the latter to get out of repair from the alternate expansion and contraction of the iron plates. To obviate, in some measure, this inconvenience from expansion and contraction, some cast the plates in the form of a half cylinder, without flanges, and lap them one over another in the manner of tiles; but a straight flue, with plates joined by flanges, is preferable; and, to avoid all inconvenience from the above cause, the middle plate in the series should be bolted, or otherwise permanently fastened to the brick part of the flue, so that the plates may elongate from the centre towards each end: the terminating plate at each end of the flue should not be confined by the wall, but allowed to slide into an aperture fitted to receive it. The flues should be about one foot asunder, to allow room to pass between them. The wooden platform of bars, from which the cloth is hanged, should be suspended from the beams, and about four feet below them; or, a double row of beams may be put in in the first instance, and the cloth bars affixed to the lower row. A flight of stairs, and tackle, or wheel, should be attached to one end of the building, under a projecting part of the roof, by which the wet cloth is conveyed into the upper part of the building, and let down from the bars. The only entrances into the building are by a door at the top of the stairs, for the introduction of the cloths, the bottom of which to be on a level with the grated floor, and another at the lower part, to allow the workmen to enter occasion-

ally for repairs or examination of the flues. The lower door may also serve for ventilation when required. A row of small windows, one pane in height, and three or four in width, placed at a distance of ten or twelve feet on each side of the building, and about five feet from the ground, will afford sufficient light. It would be well to have double windows, and the sashes well cemented in, to prevent loss of heat on the one hand, and admission of air on the other. The doors should be made to shut close. A net work of wire must be suspended over the flues their whole length, and about four from their upper surface, to mark the nearest approach that the cloth can make to the flues, and to catch any piece, or end of a piece, which may accidentally fall from above.

The method of operating is extremely simple; as soon as the goods are introduced and suspended, the fires are kindled, and the doors closed; the heat is continued till the cloth is dry. The operation may require from two to three hours according to the quantity of moisture in the cloth and the heat employed. The state of the cloth can be ascertained from time to time by examination through the lower door. When the cloth is dry, the doors should be thrown open to admit the air, and expel the atmosphere of steam. The cloth must now be removed as expeditiously as possible, and, if another lot of wet cloth is not ready for drying, the doors and the apertures in the roof must be closed, by valves made for that purpose, in order to preserve as far as possible the heat accumulated in the flues and walls of the building for use at another time.

The reader will observe, that the process of drying here recommended is essentially different in principle from the one recommended in the preceding article. The object of this arrangement is to exclude as much as possible the agency of air; there is, properly speaking, no ventilation, unless the apertures in the roof for the escape of vapour be accounted such; the operation is conducted on the same principle as the evaporation of water from a steam-boiler, in which case we apply the heat at the bottom of the vessel, and make a vent at the top for the escape of steam. If we consider this drying room, (while in operation,) to represent the steam-boiler, and the moisture in the cloth the water of the boiler, the analogy is complete. The air has nothing to do with the process, and should have nothing to do with it. Mr. Tredgold's calculations proceed on the principle of making air the medium of communication of heat to the wet cloth, (instead of applying the heat immediately to the cloth itself;) which is as unnecessary, and, in fact, as absurd as it would be to attempt to evaporate water from a boiler, by heating a current of air and passing it through the water to be evaporated. Evaporation might, indeed, be carried on in this

way, but certainly with great loss of heat; for the air, which is in this case the carrier of heat, must pass out of the water at a temperature, at least, as elevated as that of the vapour formed; and of course, all that caloric which has raised its temperature from that of the atmosphere, to that of the watery vapour, is lost.

The error on this subject, which is nearly universal, both with practical men and writers, probably originated from associating the idea of drying by artificial heat, with that of drying by air exclusively. In the last case the freer the circulation of air the better, because the heat, which supplies the evaporation, is derived wholly from that source, and the notion very naturally occurred that the two operations might be economically combined; but they cannot be united, not even in the driest state of the atmosphere. If it be asked what is to expel the vapour that is formed from the drying-room when the admission of air is prevented, the answer obviously is, the same power that expels the steam from a steam-boiler; the successive portions of steam as they form must expel the preceding: at the close of the process, there will of course be an atmosphere of steam in the room, but that is driven off by almost the first gush of air, on opening the lower door.

If steam-heat be preferred on account of its greater safety, or from any other cause, it should be applied on the same principle as above recommended, merely by substituting horizontal steam-pipes for the fire-flues; the construction of the drying-room in every other respect may be the same.]

## AIR-STOVES.

A current of heated air may also be made the means of distributing heat, and is a more simple and elegant mode of attaining the whole effect of the fuel than when steam is made the agent of heating.

### *Belper Stove.*

The first person who made any material improvement in the air-stoves in England was Mr. Strutt, of Derbyshire, for the purpose of warming his extensive cotton-works more uniformly and with greater economy than formerly. The first, or most simple plan of these stoves, was, that of enclosing an iron furnace, called a cockle, in a mass of brick-work, leaving an empty space of a few inches all round it, in order to allow a current of air, admitted by passages below, to come in immediate contact with the whole surface of the iron chamber and pipe. This air, after being heated, and consequently rarefied, would naturally ascend towards the head of the stove, and pass

through one or more apertures into the room required to be warmed.

The brick-work was built of considerable thickness round the cockle of these stoves, in order to prevent the escape of heat in the immediate vicinity of the stove, and of course, to economise the fuel more effectually; as they were sometimes built in other apartments than that which is required to be heated. From the whole of the lower part of the cockle being the receptacle of the ignited fuel, it is obvious that its exterior will often be elevated to nearly the same temperature as the inside; consequently a current of air passing over its exterior surface will become heated in a proportionable degree to the rapidity of its passage.

This method of heating air is, undoubtedly, the most economical which has been hitherto devised in this country, as all the disposable heat given out by the fuel, with the exception of what is necessary to carry off the smoke, is absorbed by the air in its passage through the air chamber of the stove. And it affords a most convenient method of disseminating heat.

It appears from an experiment made with the Derby stove hereafter described, that one pound of coal will raise 5085 cubic feet, or 339 pounds of air through 59 degrees, which is equivalent to one pound of coal rising 20,000 pounds of air one degree.

In heating by steam we have, by Buchanan's calculation, in the place of 66 pounds .6, or 933 cubic feet of air, at 140° in one minute, only two pounds of steam furnished in the same time, and with the same fuel.

If the steam were all condensed and the water cooled down to the temperature of the room, it would be, doubtless, nearly equal to the effect produced by the warm air heated by the same weight of coal. But we see, from facts derived from good authority, that steam falls very short of the effect produced by making air the vehicle of heat.

In the first place, the heat lost in the conveyance of steam is much greater than that lost in conveying air. The temperature of the steam is 212°, that of the air only 130°. But the greatest difference is caused by the ratio of the surface to the solid content of the air-channel being only one 30th that of the steam-pipe to supply the same sized room.

Another source of deficiency in heating by steam, which must be very considerable, is the heat which escapes with the hot water and uncondensed steam.

The steam-pipes exposed in the rooms in which the steam is condensed are, probably, always about, but never less, than 180°. At this temperature only one half of the original steam is condensed, and, of course, they give out only half the heat

which would be given out if the condensed water were allowed to cool down to the temperature of the room. This loss, with those already stated, will go far to explain the great difference in favour of warming by air.

Notwithstanding the obvious advantages of air-stoves in point of economy, for heating extensive cotton-mills or other manufactories, and warming hospitals, prisons, or other buildings where open fires would either be impracticable or unsafe, the plan was not sufficiently made known to the public, nor its economical advantages pointed out, until it was mentioned by Mr. Buchanan, in his "Essays on the Economy of Fuel and Management of Heat," published in 1815. Since this period, Mr. Sylvester, in his very able work, "The Philosophy of Domestic Economy," has called the attention of the public to the great importance of the question, by showing the beneficial application of an extensive stove of this kind, erected in the Derby Infirmary, and the Pauper Lunatic Asylum at Wakefield.

It is far preferable that the area on which a stove of this kind is to be erected, should allow of a parallelogram subterranean passage, three times as wide as it is high, being carried out, communicating with the external atmosphere at some convenient distance from the building, in order to allow of producing a current of cool air for the purposes of ventilation in the summer season, as well as for the supply of the stove for warming the air of the apartments in winter. The stove should also be erected as near the middle of the area of the building as convenient, and be placed, if possible, from six to twelve feet below the floor, in order to preserve as much uniformity as possible in distributing the warm air through the edifice.

Fig. 60, represents a section of the cockle, and air-stove erected at the Derby Infirmary, and fig. 61, a transverse section of the air-stove, exhibiting the masonry surrounding the cockle, as given by Mr. Buchanan. The cockle, *a*, is made of a cubical form, with a dome, or rather groined arch top, about three or four feet high; and is made of plate or wrought-iron about three-sixteenths of an inch thick, riveted together like the ordinary boilers of steam-engines. The smoke passes off by a narrow passage, *b*, at the base of the cockle, into the flue, *c*, which leads to the chimney. The brick-work, surrounding the cockle, is built with alternate openings as represented in the side view, at *f*, at about eight inches distant from the sides of the cockle. Through these apertures, *e*, pipes are inserted, which may be made either of sheet-iron or common earthenware, so as to extend within an inch of the cockle, by which means the air to be heated may be thrown near, or in immediate contact with the surface of the cockle if desirable; which was found by Mr. Strutt to double the effect derivable from the same quantity of fuel.

The horizontal partition of the air-chamber, represented at *d*, cuts off the communication between the lower and the upper portion of the air chamber. The arched openings in the lower half at *g*, exhibit the openings of the main air-flues leading from the exterior atmosphere.

The air passing from these lower flues, *g*, through the apertures beneath the

horizontal partition, *d*, and coming in immediate contact with the body of the stove, must find its way into the upper air-chamber, *h*, through the numerous apertures or pipes in the upper division, by which circuit its velocity will be sufficiently retarded to obtain the necessary elevation of temperature from the heated cockle.

In order that the air may not be injured for the purposes of respiration, the size of the fire-room in Belper stoves must be so regulated as not to heat the cockle or body of the stove, at an average, above the temperature of 280° Fahrenheit according to Mr. Sylvester, or 250° according to Mr. Tredgold, when the air is intended to supply living rooms, but for drying-rooms more heat may be given, if the saving of time is an object, but still it is more economical to dry at a lower temperature.

From the upper or hot air-chamber, *h*, a main hot air-flue, *i*, leads to each of the floors which are to be heated. The horizontal and inclined parts of these main flues should be made of brick or stone, and if they have to pass under ground, be secured in a case. The vertical parts may be made of sheet-iron, or even well-seasoned wood.

An opening over the door of each room allows the entrance of the heated air into the several rooms; and a flue from the bottom of each room proceeds to the roof of the building, from whence the whole of the air is discharged by a turncap, the mouth of which is by a vane kept constantly from the wind.—The outlet flue in each room has also an opening near the ceiling, which is used in summer to increase the ventilation, but kept shut in winter.

When the stoves of the Pauper Lunatic Asylum at Wakefield are in full action, the air on the average moves with the velocity of five feet in a second. The area of each of the two main flues is twelve superficial feet, which gives 120 cubic feet for the quantity which passes through the whole house in every second. Supposing the cubic content of the house to be 400,000 cubic feet, the whole of the air in it will be changed in a little less than every hour.

Provided a stove of this construction is well built, and so managed as not to allow the warmed air to attain too great a temperature, it is not only much more economical than any other method for warming extensive buildings, but it is equally salubrious with the more recent mode of employing steam-pipes for this purpose, if not more so. The principal disadvantages of the plan appears to be that it cannot be easily applied to an extensive building unless constructed during the erection of the edifice. It is also difficult to give a tolerable appearance to the several parts.

As the air passages of this kind of stove ought to be placed several feet under ground, it affords also a convenient mode of admitting a portion of cold air to the interior of the building in the summer season, as well as supplying heated air in the winter.

The change in temperature of the air by passing in this way, Mr. Sylvester says, is much more than could be supposed. The cold air-flue at the Derby Infirmary is about four feet square,

Fig. 60.

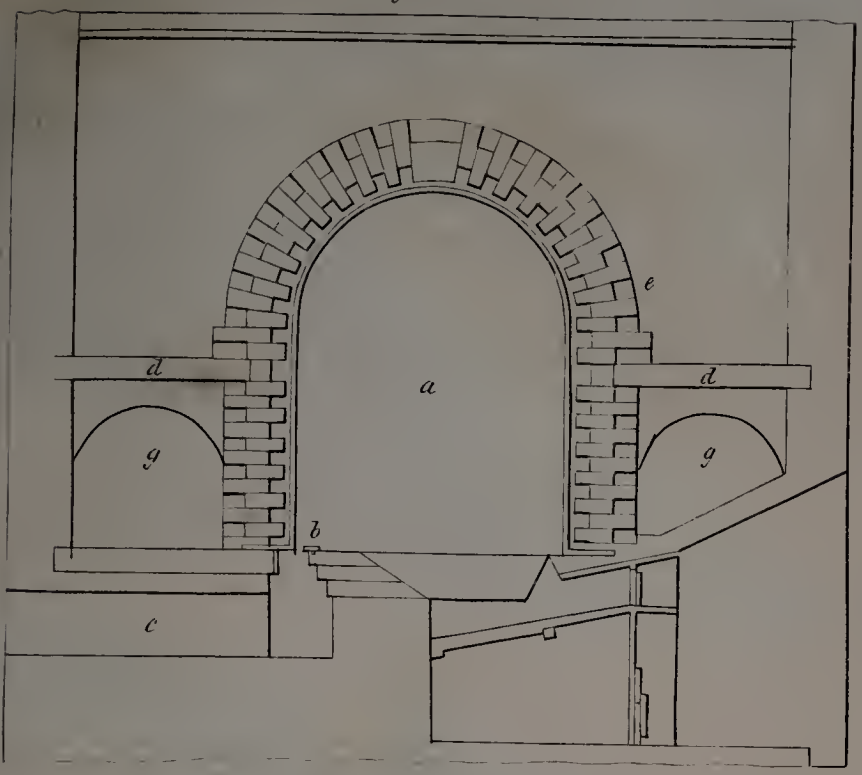
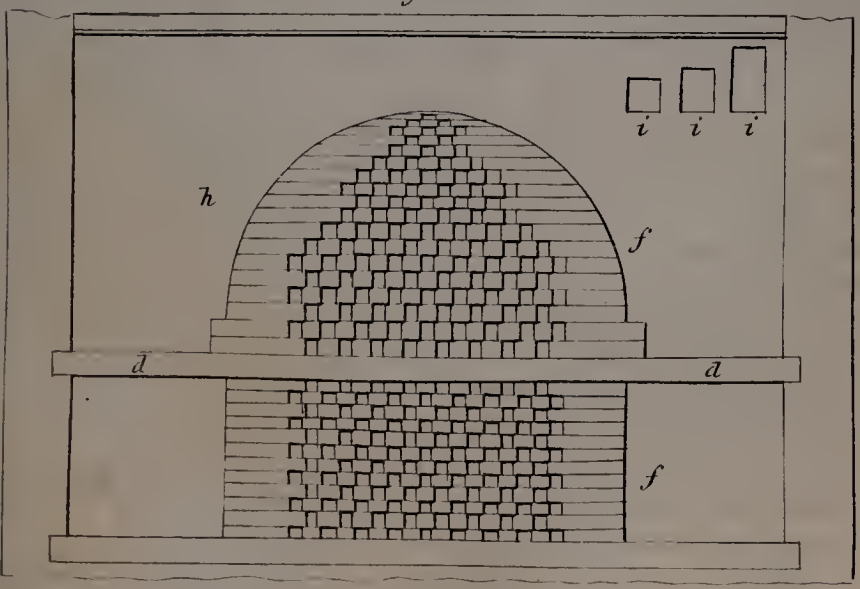



Fig. 61.



and its length seventy yards. In the month of August, when the thermometer in the shade stood at 80°, the air which entered the air-flue under ground at the same temperature, was found to be 60° at the extremity where it entered the stove-room: the current at this time was sufficient to blow out a lighted candle. In another experiment, when the outer air was at 54° this air was reduced to 51° by passing through the flue.

This is a great advantage of the air-stove above the use of the steam apparatus, since this last only supplies the deficiency of heat in winter, but has no tendency to check it when that of the atmosphere is beyond the medium temperature of the earth.

## HOT-BEDS.

Chemists formerly used in their laboratories another kind of heating apparatus, under the quaint title of balneum ventris equini, the horse's-belly bath, being a bed of hot horse-dung; and this apparatus is still used in some chemical manufactories, as in those of white lead and verdigris, and particularly by gardeners for hastening the germination of seeds, or warming the frames in which tender plants are kept.

The fermenting substances used in forming hot-beds are stable litter or dung, in a recent or fresh state, tanners' bark, leaves of trees, grass, and the herbaceous parts of plants generally.

Stable dung is in the most general use for forming hot-beds, which are masses of this dung after it has undergone its most violent fermentation. These masses are generally in the form of solid parallelograms, of magnitude proportioned to the number of vessels to be placed in them, or the size of the frames which are to be placed on them, the degree of heat required, and the season of the year in which they are formed.

The formation of dung-beds is effected by first marking out the dimensions of the plan, which, if intended to heat garden-frames, should be six inches wider on all sides than that of the frame to be placed over it, and then by successive layers of dung laid on by the fork, raising it to the desired height, pressing it gently and equally throughout.

Tanners' bark is only preferred to dung, because the substance which undergoes the process of putrid fermentation requires longer time to decay. Hence it is found useful in white-lead works, and the bark-pits of hot-houses, as requiring to be seldomer moved or renewed than dung.

The Hon. Mr. Boyle used moist hay in his laboratory, for digestions and putrefactions.

Horse-dung is by some mixed with bark, with ashes, with leaves, saw-dust, shavings, clippings of leather, chopped spray, and such other durable substances as can be brought to ferment along with it, and prolong its duration as a fermenting mass.

A mixture of leaves with stable litter is recommended, using only a little bark, fifteen or eighteen inches deep at top, in which to plunge the pots. But in using leaves, or leaves mixed with litter, they must always be well fermented, and the rank heat extracted out of them before they are made up into a bed.

Flax dressers' refuse ferments very slowly and regularly, and, used instead of stable-dung in forming hot-beds, it will keep up a steady heat longer than almost any other substance.

Oak-leaves are said to be preferable to those of any other sort. The leaves of beech, Spanish chesnut, and horn-beam, will answer the purpose very well. It seems that all leaves of a hard and firm texture are very proper; but soft leaves that soon decay, such as lime, sycamore, ash, and of fruit trees in general, are very unfit for this mode of practice.

A very considerable ground of preference is the consideration that decayed leaves make good manure; whereas rotten tan is of no value. It has been tried both on sand and clay, and on wet and dry lands, and it never deserved the name of manure; whereas, decayed leaves are the richest, and of all others the most suitable manure for a garden. But this must be understood of leaves after they have undergone their fermentation, which reduces them to a true vegetable mould. This black mould is also, of all others, the most proper to mix with compost earth.

Leaves mixed with dung make excellent hot-beds; and beds compounded in this manner preserve the heat much longer than when made entirely with dung. In both cases the application of leaves is a considerable saving of dung.

The object of preparation in all these substances being to get rid of the violent heat which is produced when the fermentation is most powerful, it is obvious that preparation must assist in facilitating the process. For this purpose, a certain degree of moisture and air are requisite; and hence the business of the operator and gardener is to turn them over frequently, and apply water when the process appears impeded for want of it, and exclude wet and damp when it seems chilled and impeded by too much water.

In winter, the process of preparation in gardens generally goes on under sheds, which situation is also best in summer, as full exposure to the sun and wind dries the exterior surface too much; but, where sheds cannot be had, it will go on very well in the open air.

A great deal of heat is undoubtedly lost in the process of fermentation; and it has been attempted to turn this heat to some account, by fermenting dung in houses or sheds, with shelves, or in vaults under rooms. The latter mode seems one of the best in point of economy, and is capable of being turned to considerable advantage where common dung beds are extensively used; but the most economical plan of any seems to be that of employing only Mc Phail's pits, or such as are constructed on similar principles; namely, by sinking a pit, considerably larger than the intended garden-bed or chamber for the chemical vessels, lining it with bricks; and then constructing, at a sufficient distance within it, an inner wall, having holes disposed chequerways to allow the heat to penetrate into the chamber that is formed by this interior wall. The dung or other fermenting substances is thrown into the space between the inner and outer walls of the pit, and being covered over with boards, or a layer of earth, the heat passes through the holes of the inner wall into the chamber, and heats the digesting vessels, which are piled up in a stack, and the chamber closes with a falling door, or it supplies bottom heat to a bed of earth, laid upon boards near the top of the chamber, just above the highest row of holes.

This is a very cleanly method of applying the heat of fer-

menting dung or vegetable matter to chemical and horticultural purposes.

### *Mills' Pyrometer.*

The expansion of air constituted the basis of the original thermometer by Fludd; spirit of wine and quicksilver were then employed in preference, but Mr. Mills has returned to air. Dr. Hook found that the heat of summer expands the ordinary air about a 30th part; and Mr. Boyle, in his History of Cold, alleges his own trials, proving that the force of the strongest cold in England does not contract the air above a 20th part; so that the sum of a 20th and a 30th part being a 12th part, we may conclude that the same air which is extremely cold occupies twelve parts of a space, will in very hot summer weather fill thirteen such spaces; which is as great an expansion as that of spirit of wine when it begins to boil; for which reason, and for its being so very sensible of warmth or cold, and continuing to exert the same elastic power after being so long included, it is the most proper fluid for the purpose of thermometers.

Dr. Hales found, that when an empty retort was exposed to the fire, until its bottom was red hot, the air contained in it was expanded to a double space; and in a white heat to a triple space.

The want of an apparatus to measure the higher degrees of heat above the temperature of boiling quicksilver, more conveniently than by Mortimer's or Wedgwood's thermometers, is much felt by potters, smelters of ores, and many other artists.

Mr. Mills' instrument, as represented in fig. 62, is founded upon the expansion of air by heat, and is composed of a platinum bulb and stem, drawn out without any joint. The bulb, *a*, is hollow, and about half an inch in diameter; the stem, *b*, must be perfectly cylindrical, and about one-sixteenth of an inch in diameter on the inside.

This tube is attached, or rather soldered, by an air-tight joint, to a glass pipe, *c*, which is first bent in an angular direction, and then into the form of an inverted syphon, *c, d*. The upper extremity of the pipe is blown into a bulb, *d*, of the same size internally as the platinum bulb, *a*, a funnel-shaped opening being left at first for the introduction of a sufficient quantity of quicksilver; after which this opening is closed by the action of the lamp. A scale, *e*, is attached to that leg of the inverted syphon, which is farthest from the platinum bulb and stem.

When the platinum bulb, *a*, is put into the fire, the air contained within it is expanded by the heat, and pressing upon the quicksilver contained in the legs of the instrument, forces it up more or less toward the glass bulb, *f*, according to the greater or less heat to which it is exposed.

As the platinum bulb would be corroded and destroyed by exposure to the fire naked, a crucible, *g*, of very refractory clay, is used, to defend it: the platinum bulb and part of the stem is placed in it, and the remaining space filled up with powdered charcoal or sand.

It is evident that by using this pyrometer the heat of any furnace may be read off on the scale, during the whole of any

process, and a greater degree of certainty as to the administration of the fire obtained, than at present.

### *Lamp Light.*

This is probably the oldest method of illuminating dwellings, and yet, notwithstanding the importance of the subject, the relative value of the oils, used for burning in them, has been much neglected by chemists.

Leutman, in his Vulcanus Famulans, an excellent German treatise on the heating and lighting of our dwellings, published in 1723, and which has run through repeated editions in Germany, although unknown in England, seems to have been the first that made any experiments on the duration of the burning of the different kinds of oil.

The oils he enumerates as being then those most usually burned in lamps, are olive-oil, rape-oil, linseed-oil, poppy-oil, gourd-oil, sunflower-oil, and walnut-oil; he gives the preference to olive-oil, for night lamps, and says two pounds of it will burn as long as three pounds, or three pounds and a-half, of rape-oil.

The experiments of succeeding authors confirm the superiority of olive-oil, and the principal of them are here given.

Scopoli made the following experiments on the burning of several vegetable oils, both as to the duration of the flame, and the quantity of soot that they yield while they are burning.

Half an ounce of nut-oil was three hours and four minutes in burning, and it yielded twelve grains of soot.

Half an ounce of linseed-oil was three hours and twenty-nine minutes in burning, and it yielded eleven grains of soot.

Half an ounce of olive-oil was two hours and fifty-five minutes in burning, and it yielded only one grain of soot.

Half an ounce of rape-oil was three hours and twenty-four minutes in burning, and it yielded three grains of soot.

Half an ounce of nettle tree oil, (celtis australis) was two hours and forty minutes in burning, and it yielded only half a grain of soot.

These experiments demonstrate the superiority of olive-oil, and the nettle tree oil.

The following experiments on this subject are related in Nicholson's Journal, for Nov. 1812; which show not only the quantity of oil consumed in an hour, but also the time that the lamp took to boil 2000 grains, or rather more than a quarter of a pint of water.

| | Oil consumed in grains | Time of boiling in minutes. |
|---|---|---|
| An argand's lamp | 444 | 7 |
| The same, new trimmed | 500 | 6⅓ |
| The same, without the glass | . | 7¾ |
| The same, with a glass, two inches in diameter, and one inch and a half high | 400 | 6½ |

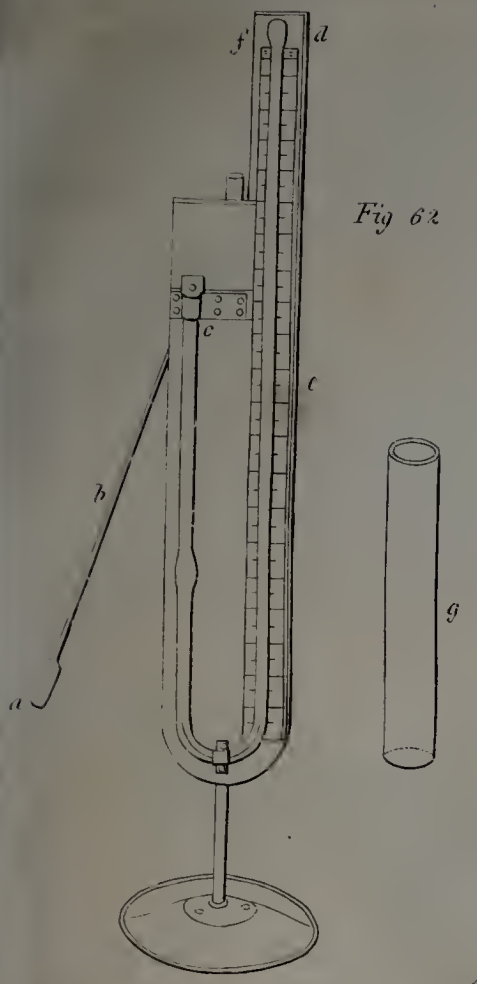



Fig 62

Fig. 63.

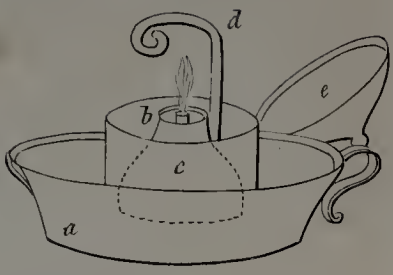
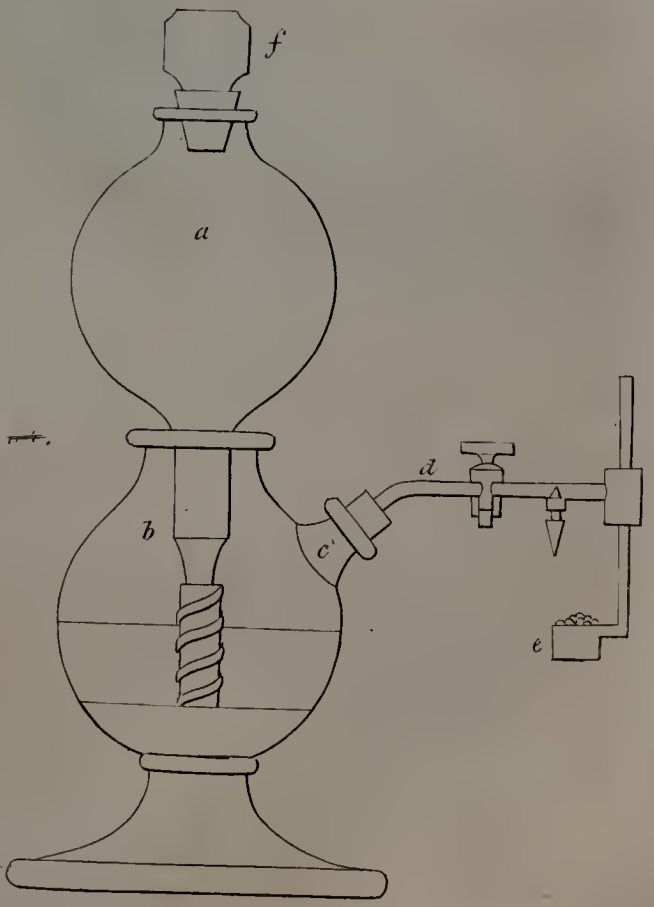



Fig. 64.



| | Oil consumed in grains. | Time of boiling in minutes. |
|---|---|---|
| Tin lamp, with four burners of eight threads, and an air-tube in the centre | 200 | 10 |
| Tin lamp, with eight burners of four threads, and air-tube | 300 | 6½ |
| The same, with only three threads, and a glass two inches wide, and one inch and a half high | 320 | 6½ |
| The same, with a glass only one inch high | 276 | 6¼ |
| A lamp, there described, with 8 burners | . | 3½ |
| 7 | . | 4 |
| 6 | . | 4¼ |
| 5 | . | 6 |
| 4 | . | 6¾ |
| 3 | . | 9½ |
| 2 | very slightly in | 15 |
| 1 | only simmered in | 30 |

Lately, Mr. Joseph Hecker, director of the salt-works, and administrator of the mines at Iruskawitz, in Gallicia, has found that naptha burns much better than oils of other substances, in mines containing bad air, and injures the health of the workmen less.

The light of petroleum is to that of German rape-oil, as 1000 is to 831.3, and to that of tallow, as 1000 is to 500.3, supposing that the first burns with a small flame. The quantity of naptha burnt for lighting the same space, is to that of tallow, as 1000 is to 925.74, and to that of German rape-oil, as 1000 is to 673.28. Coal-tar oil, which is in the same proportion as naptha, is preferable to it, being less expensive: oil of bones is that which yields the most brilliant light.

In the lighting of mines containing bad air, German rape-oil and tallow will extinguish, when naptha, petroleum, and the oil of bones, will still burn; but naptha and petroleum are more readily extinguished by a slight motion of concussion in the air; the oil of bones being, in this case, best for use.

M. Hecker has found that in mines where the oxygen had diminished to 18.33 per cent., men are not incommoded. Generally, tallow, or German rape-oil, is extinguished in air containing not more than 18.1 per cent. of oxygen, whilst naptha and oil of bones burn when it contains no more than 18.8 per cent.

Persons who cultivate the higher parts of science are often negligent in publishing minute improvements in their means of research, on account of their considering them of too slight value individually; although, when a number of them are collected together, their aggregated value becomes considerable.

Mr. James Smithson observed much inconvenience from the usual length of the wick of lamps, as occupying a large space in the reservoir for oil, and thus requiring that it should be of

considerable size: and he has found that it is by no means necessary that the burning part of the wick should be a continuation of that immersed in the oil: it being this circumstance that occasions the long wick to be used in order that it may allow for a portion of its length to be cut off daily for the purpose of trimming, as it is called, the lamp. He finds it quite sufficient if the wick tube of the lamp merely contains a short bit of cotton wick, no longer than is just sufficient to reach nearly to the bottom of the oil; or instead of spun cotton the tube may be merely filled with cotton wool, lightly packed, to allow free passage to the oil.

To supply the burning part of the wick, a short and thick bit of wick, or cotton wool rolled up, may be placed on the top of the tube. This loose burning part of the wick receives the supply of oil from the cotton in the tube, and may be renewed as often as it clogs up with the carbonaceous residuum left by the oil on combustion. In the same manner, a very short loose ring of wick may be applied to the common wick of the argand lamps.

There are a class of oily bodies, not sufficiently solid to form into candles, and yet too thick to burn well in lamps, unless some means are used to keep them melted.

Fig. 63, represents a lamp made for the purpose of burning hog's lard, cocoanut oil, or any other concrete oil.

*A*, represents the outer pan of the box lamp; *b*, the inner pan; *c*, the metal burner, cast solid, with a hole in the centre for the wick; *d*, the wire cast in the burner, of sufficient length to be brought over the flame, which having contracted heat communicates the same to the burner, thereby keeping the animal matter, &c. in a liquid state; *e*, the cover to keep out the dust, &c. when the lamp is not in use.

Notwithstanding lamps of this kind were made and sold many years ago, Major Cochrane has taken out a patent for lamps of a similar construction.

## *Wax Lamps.*

The use of oil for lamps, especially when a person wishes to carry one with him in travelling as a night light, is very disagreeable on account of its liability to be spilled; and the almost utter impossibility of confining oil in any kind of bottle, or lamp, by either ground or screw stoppers; and the consequent greasiness that it communicates to whatever is in contact with the vessel in which it is contained.

Some difficulties certainly occur in attempting to substitute wax for oil in lamps, but the greater cleanliness of wax gives an interest to the subject.

The great secret on which the burning of wax lamps depends, is the affording a supply of melted wax to the wick

immediately upon its being lighted; for this purpose, care should be taken that bits of wax should be heaped up in contact with the wick, so that the flame may melt it instantly.

The wicks of Mr. Smithson's wax lamps are made of a single cotton thread, waxed by drawing them through melted wax: it is supported by a burner made of a small bit of tinned plate; which has two slits cut at each end, and the middle parts raised up to form a wick holder. A cup is the only vessel necessary for a wax lamp, the wax being cut to pieces and pressed into it: when a wick is consumed it is only necessary to pierce the wax with a large pin down to the burner, and introduce a fresh piece of waxed cotton.

If the wax lamp is required to have a thicker wick, as for experiments with the blow-pipe, the wick may be made in two pieces, as for the oil lamp, and only the detached end will want occasional renewal.

The best manner of extinguishing wax lamps so as to preserve the wick for re-lighting, is to overcharge it with wax, by holding a piece so that as the wax melts it may fall on the wick, and lessen the flame, when a gentle puff will extinguish it at once without any ill smell.

These wax lamps have a superiority over wax candles in that the flame being always at the same height, it admits a vessel of water being supported over it, ready to be used for shaving in the morning; or coffee may be kept warm over it, to the great convenience of travellers by early stage coaches; while, at the same time, the wax will congeal so quickly on the putting out of the flame, that it is ready to be packed up among the baggage, or clapped into the night bag, before the traveller has finished his dressing.

### *Candle Light.*

The use of candles for illuminating rooms is, in general, much neater than that of lamps; but those made of tallow are very troublesome, on account of the continual snuffing that they require.

This constant attention is severely felt by persons engaged in works that require mental labour: it may, however, be in some measure avoided, by placing the candle in a slanting position, so that the end of the wick may not collect the soot in the form of mushrooms, but stick out beyond the side of the flame, and be gradually burned to ashes.

As wax and spermaceti candles are made with thinner wicks, the wick is unable to support itself, and, therefore, bends to the side of the flame and is consumed, although the candle is placed upright.

To prevent, however, the liability of the tallow to overflow

and gutter away, the candle should not be placed sloping until the wick has acquired some length, from the burning of the candle in its usual upright position.

In case two candles are used on the same table, they should not be placed too nigh together, lest the tallow should grow soft by their joint heat, and the candles gutter away.

This sloping position has been long adopted for the watch candles used for night lights.

No general rule can be given for the proper slope, as this depends on the thickness of the wick, and the greater or less twist given to it.

To ascertain the effect of snuffing on the consumption of tallow in candles, six candles of the best animal tallow cast in the same mould, with wicks of twelve threads, were burned for one hour. The following are the results.

*Snuffing every ten minutes.*

| Weight in grains when lighted. | After one hour. | Loss. |
|---|---|---|
| 781 | 676 | 106 |
| 782 | 682 | 100 |
| 784 | 682 | 102 |
| 785 | 681 | 104 |
| 786 | 676 | 109 |
| 792.5 | 690 | 102.5 |

*Without snuffing.*

| | | |
|---|---|---|
| 673 | 573 | 100 |
| 676 | 573 | 103 |
| 676 | 570 | 106 |
| 681 | 581 | 100 |
| 689 | 580 | 101 |
| 689 | 592 | 97 |

With a view to ascertain the comparative combustibility of piney tallow, a new kind of concrete oil brought from the East Indies, candles of the materials under-mentioned were cast; one mould was used for all, and the wicks were composed of an equal number of threads, except that the wick of the wax candle was made smaller. Having been accurately weighed, they were burned for one hour in an apartment in which the air was kept still, and at a temperature of 55°.

| | Weight in grains when lighted. | At the end of the hour. | Loss. |
|---|---|---|---|
| Wax | 840 | 719 | 121 |
| Half wax, half piney tallow | 770 | 631 | 139 |
| Spermaceti | 760 | 604 | 156 |
| Half spermaceti, half piney tallow | 777 | 605 | 152 |
| Animal tallow | 811 | 703 | 108 |
| Half tallow, half piney tallow | 792 | 681 | 111 |
| Cape wax | 763 | 640 | 123 |
| Piney tallow | 812 | 702 | 110 |

These experiments also show the comparative value of the most usual materials of which candles are made.

Candles were made in the same mould as before, wicks composed of twelve threads, the number used in wax candles of the size employed. It was also contrived to cast a wax candle for the sake of more perfect comparison.

The following are the results of an hour's combustion:

| | Weight in grains when lighted. | At the end of one hour. | Loss. |
|---|---|---|---|
| Wax - - - - | 730 | 594 | 136 |
| Half piney tallow, half wax - | 750 | 622 | 128 |
| Spermaceti - - - | 736 | 590 | 146 |
| Half wax, half sperm - - | 762 | 616 | 146 |
| Piney tallow - - - | 774 | 684 | 90 |

Mr. John White took out letters patent for a method of making candles whose outer surface being less fusible than the interior mass, serve as a vessel to contain it. The moulds used by him for manufacturing his candles are a drawn or hollow tube. He then melts as much wax, spermaceti, tallow, or any other material or compound fit for, or adapted to, the making of candles, as is equal to fill one third of the mould, or any such quantity as may suit the fancy. When the material is poured into the mould in a fluid state, he immediately lays the mould down lengthways, and keeps it constantly going round until the material inside of the mould is fixed or congealed round the side of the mould. Thus a case or hollow cylinder will be formed from the fluid material very true, and exactly the size, shape, and length of the mould. This case, or cylinder, when discharged from the mould, forms the outside of the intended candle, which may be cottoned and filled up at pleasure, in the usual way, with some material of greater fusibility, which forms a regular candle.

The patentee avers, that candles manufactured by this means can be made to look superior to wax, and vary in price according to quality, from a little more than the price of tallow to two-thirds of the price of wax, and answer all the purposes of wax-candles, not requiring snuffing, afford equal or superior light without having a greasy appearance, and acquire a fine high polish by friction; may be used in any weather or climate without losing their solidity, polish, or beauty, and completely removes the disagreeable smell and feel arising from the use of tallow candles.

In Bavaria, they have lately adopted the use of wooden wicks; but in what their superiority consists does not appear.

## *Comparison of Lamps and Candles.*

Count Rumford states, that the relative weight of the undermentioned inflammable substances, required to produce an equal degree of light, is as follows:—

A good wax candle, kept well snuffed, and burning with a clear bright flame, - - - - - - - - - 100
A good tallow candle, kept well snuffed, and burning with a bright flame, - - - - - - - - - 101
The same tallow-candle, burning very dim for want of snuffing, - 229
Olive-oil, burnt in an argand's lamp, - - - - - 110
The same burnt in a common lamp, with a clear, bright flame, without smoke, - - - - - - - - - 129
Rape-oil, burnt in the same manner, - - - - - 125
Linseed-oil, burnt in the same manner, - - - - 120

The Count would have been glad to have made another

experiment with whale-oil; but there was none to be had in Bavaria, where he then lived.

A few years ago, the following experiments were made by Dr. Ure, on the different quantities of light produced by candles of different sizes, and by an argand lamp:—

Dipped candles, ten to the pound, burnt four hours thirty-six minutes. As they weighed 672 grains each, of course, just 150 grains of tallow were consumed in an hour: and the light given out, being measured by the shadow it produced at a certain distance, was estimated by him as a kind of standard, and called thirteen.

Mould-candles, ten to the pound, burned five hours, nine minutes. As they weighed 682 grains each, of course, 132 grains of tallow were consumed in an hour: the light given out was estimated at twelve and a half.

Mould-candles, eight to the pound, burned six hours, thirty-one minutes. As they weighed 856 grains each, of course, 132 grains of tallow were consumed in an hour: the light given out was estimated at ten and a half.

Mould-candles, six to the pound, burned seven hours, two minutes and a half. As they weighed 1160 grains each, of course 163 grains of tallow were consumed in an hour; the light given out was estimated at fourteen and two thirds.

Mould-candles, four to the pound, burned nine hours, thirty-six minutes. As they weighed 1787 grains each, of course 186 grains of tallow were consumed in an hour: the light given out was estimated at twenty and a quarter.

A Scotch muchkin, or English pint of good seal-oil, weighing 6010 grains, burned in an argand lamp eleven hours, forty-four minutes; of course, 512 grains of oil were consumed in an hour: the light given out was estimated at sixty-nine and four tenths.

It follows, from these experiments, that the same quantity of light is procurable from these different numbers:—

| | | | |
|---|---|---|---|
| 2 lamps, or | 7 | mould-candles, | 4 to the pound. |
| 1 ——— | 5 | ——— | 6 ditto. |
| 5 ——— | 33 | ——— | 8 ditto. |
| 4 ——— | 21 | ——— | 10 ditto. |
| 3 ——— | 16 | dipped-candles, | 10 ditto. |

From these experiments, having the price of oil and tallow by the pound, the relative value of each may be easily found.

The quantities of light given out were measured in the usual manner, by placing the two lights a few inches apart, and at the distance of a few feet from a sheet of white paper stuck upon the wall. On holding a small card near the wall, each light casts a distinct shadow, the brightest light casting a darker shadow than the fainter light. On removing the brighter light farther from the card, or putting the fainter light nearer the card, the two shadows may be brought to the same shade of colour. The distance of the two lights from the card is then to be measured, and squared; the portion between the squares shows the proportion between the degrees of light given out by each light. Thus, if an argand lamp at ten feet distance from the card, and a candle at four feet distance cast shadows equally deep; we shall have the square of ten, that is, one hundred, for the estimated intensity of the light of the lamp; and the square

of four, that is, sixteen, for that of the candle; whence the light of the lamp is about six times and a half that of the candle.

### *Gas-Light.*

When coal is subjected in close vessels, to a red heat, it gives out a vast quantity of gas, which, being collected and purified, is capable of affording a beautiful and steady light in its slow combustion through small orifices. Dr. Clayton, in 1739, seems to have been the first who performed this experiment, with the view of artificial illumination, as appears by the Philosophical Transactions of that year, though its application to economical purposes was unaccountably neglected for about sixty years. At length Mr. Murdoch, of the Soho Foundry, instituted a series of judicious experiments on the extrication of gas from ignited coal, and succeeded in establishing one of the most capital improvements which the arts of late have ever derived from philosophical research and sagacity.

Mr. Murdoch, after several trials on a small scale, five years before, constructed in the year 1798, at the foundry of Messrs. Bolton and Watts, an apparatus upon a large scale, which during many successive nights was applied to the lighting of their principal building, and various new methods were practised of washing and purifying the gas. In the year 1805, the cotton-mill of Messrs. Philip and Lee, reckoned the most extensive in the kingdom, was partly lighted by gas under Mr. Murdoch's directions, and the light was soon extended over the whole manufactory. In the same year he lighted up the large Lecture-room of Anderson's Institution with coal-gas, generated in the laboratory, and continued the illumination every evening through that and the succeeding winter.

A gas jet, which consumes half a cubic foot per hour, affords a steady light equal to that of a mould candle six in the pound.

The economical statement for one year is given by Mr. Murdoch, thus:—

| | |
|---|---|
| Cost of a 110 tons of cannel coal, | £ 125 |
| —— of 40 tons of common coal, | 20 |
| Total cost of coal, | 145 |
| Deduct the value of 70 tons of coke, | 93 |
| The annual expenditure in coal without allowing any thing for tar is | 52 |
| And the interest of capital, and wear and tear of apparatus, | 350 |
| Making the total annual expense of the gas apparatus about | 400 |
| That of candles to give the same light, | 2000 |
| If the comparison had been made upon an average of three hours per day, instead of two hours all the year round, then the cost from gas could be only | 650 |
| Ditto candles | 3000 |

The peculiar softness and clearness of this light, with its almost unvarying intensity, soon brought it into great favour with the work-people. And its being free from the inconve-

nience and danger resulting from the sparks and frequent snuffing of candles, is a circumstance of material importance, tending to diminish the hazard of fire, and lessening the high insurance premium on cotton mills. The cost of the attendance upon candles would be fully equal to that upon the gas apparatus, and upon lamps much more, in such an establishment as Mr. Lee's.

From the brilliant manner in which our streets are lighted by gas than ever they were or could be with oil or tallow, there is a greater degree of security both in person and property for every class of honest men. Crimes cannot now be committed in darkness and secrecy; and as the risk of detection increases, the temptation to guilt is diminished, and thus coal gas, by the brilliant light it sheds in our streets, has worked and is now working a moral reformation. The housebreaker and pickpocket dread the lamps much more than the watchman; and no more efficacious measure of police was ever introduced into society than that from gas lights. But this is not all, lighting our streets and houses with gas is a new art, and gives birth to several new trades, and as these new trades have arisen at a time when the improved sense of society has discovered the injurious nature of the restrictions formerly imposed on industry, they are allowed to be freely exercised by any one. The same circumstance is common to many other newly-discovered arts, and by the practice of which numerous classes of men gain a livelihood. Already in our country the professions and the trades which are thus liberated from the apprentice law of the fifth year of Elizabeth are not a few, and they promise ere long to become the majority of professions and trades in society. One consequence therefore of these scientific discoveries and improvements, not at first expected from them, is to liberate mankind, without political convulsions, from the thraldom of the unwise regulations of barbarous ages.

At present, most of the large towns of this kingdom are lighted by gas, or are on the point of being so lighted. Several towns on the continent have also adopted the same expedient.

Although much apprehension was excited on the first introduction of gas lighting, by the large collection of an explosive gas, yet only one gasometer has been blown up since the practice was generally introduced; this took place in the infancy of the art, and was occasioned by a workman applying a lighted candle to the part whence gas was issuing and mixing with atmospheric air. A few accidents have occurred by the gas escaping from pipes, but these have also in general been owing to carelessness. Shops and apartments are not close enough to

keep gas confined, and even if they were, the quantity which can escape is too trifling, compared to the quantity of air in the apartments, to occasion any mischief. Coal gas is most explosive when mixed with about five parts of air. It would be therefore requisite in a room which contains 1728 cubic feet, lighted by a stream of gas, consumed at the rate of five cubic feet in an hour, that the burner should be left open upwards of fifty hours, before the mixture would become highly explosive. When coal gas is used, its offensive odour gives warning of its escape, so that one of its most noxious qualities is a valuable safeguard.

The following statement is given by Mr. Accum. An argand burner which measures in the upper rim half an inch in diameter, between the holes from which the gas issues, when furnished with five apertures one-twenty-fifth part of an inch in diameter, consumes two cubic feet of gas in an hour, when the gas flame is one inch and a half high. The illuminating power of this burner is equal to three tallow candles eight in the pound.

An argand burner, three-fourths of an inch in diameter as above, and perforated with fifteen holes one-thirtieth of an inch in diameter, consumes three cubic feet of gas in an hour when the flame is two inches and a half high, giving the light of four candles, eight to the pound.

And an argand burner, seven-eighths of an inch in diameter, as above, perforated with eighteen holes, one-thirty-second of an inch in diameter, consumes, when the flame is three inches high, four cubic feet of gas per hour, producing the light of six tallow candles, eight to the pound. Increased length of flame makes imperfect combustion and diminished intensity of light. And if the holes be made larger the one-twenty-fifth of an inch, the gas is not completely burnt. The height of the glass chimney should never be less than five inches.

According to Mr. Accum, one gas lamp, consuming four cubic feet of gas in an hour, if situated twenty feet distant from the main which supplies the gas, requires a tube not less than a quarter of an inch in the bore.

Two lamps, three feet distant, require a tube three-eighths of an inch.

Three lamps, thirty feet distance, require a tube three-eighths.

Four lamps, at forty feet, one of a half inch bore.

Ten lamps, at one hundred feet distance, require a tube three-fourths of an inch.

And twenty, at one hundred and fifty feet distant, one inch and a half bore.

### *Oil Gas.*

Gas for lighting rooms has also been obtained from various kinds of oil; and the comparative advantages of illuminating by gas, produced from oil and from coal, is thus stated by Mr. Ricardo. The gas produced from oil is much purer, and contains a much greater illuminating power than that from coal. The quantity of light produced from a given portion of oil gas is stated, by an eminent chemist, to be equal to three times the quantity produced from coal gas: from the result of Mr. Ricardo's experiments it is equal to four times; for he has found that an argand burner, giving a light equal to six candles, six in the pound, consumed only one cubical foot in the hour.

Mr. Accum states, that an argand burner of coal gas, giving a light equal to three candles, eight to the pound, consumes two

cubical feet per hour. Then as one foot of oil gas is equal to six candles, and two feet of coal gas are required to equal three candles, it follows, if the candles were given of the same size, that one volume of oil gas is equal to four of coal in illuminating power. If we take the mean of these statements it will be as one to three and a half; that is, twenty cubic feet of oil gas will give as much light as seventy of coal gas.

Oil gas requires no purification; it contains no sulphuretted hydrogen, which is one of the admixtures of coal gas, and of this all the purification to which it is submitted cannot wholly deprive it. The coal gas, therefore, acts upon all metallic substances, and, in a course of time, must seriously injure the pipes through which it passes; and its accidental escape in shops and houses must prove highly detrimental to all ornamental gildings, paintings or any thing of which metal forms a part. This cannot happen where oil gas is used; for it contains no sulphuretted hydrogen, and it is well known to have no action on metals whatever.

It may be said, that the mode adopted for purifying coal gas effectually deprives it of this noxious gas; but experience has proved that this is not the fact, as in many places the smaller copper pipes show evident marks of being strongly acted upon, the bore being gradually filled up with sulphuret of copper.

Hence the smaller bulk and greater purity of oil gas will allow of its employment in dwelling-houses without its producing the least inconvenience. If the pipes are well fitted together and properly proved before the gas is admitted into them, no annoyance whatever need be apprehended. Even if a cock should be accidentally left open and the gas allowed to escape, it may be immediately remedied, without leaving so unpleasant a smell as that arising from the similar escape of coal gas. It must, however, be confessed, that this inodorousness of whale oil gas may, in some cases, assist in causing accidents, which would have been guarded against if coal gas had been used; for, as its presence is not detected by its smell, if a cock be left open it may mix with the air of a room, and reach the exploding point without discovery, an event which could not happen with coal gas.

Some kinds of oil gas, however appear to contain sulphur, for in Paris there is a company for lighting by gas, which uses the rape oil obtained from the seeds of the Brassica oleracea arvensis of De Candolle, and it has lately been found that the sulphur contained in this seed was dissolved in the gas, and had a pernicious effect on the neighbourhood where it was consumed. The gas attacked metallic substances and affected respiration. The brass burners were soon corroded and destroyed, and filled with an efflorescence, which has been analyzed and shown to be

a sulphate of zinc and copper, a sub-sulphate of copper, phosphate of copper, and oxide of iron, with some accidental traces of silica. This shows the necessity of washing the gas thoroughly, and of not using these seeds, if the washing will not clean the gas.

In consequence of oil gas giving, in proportion to its bulk, a much greater quantity of light than coal gas, it has been compressed into strong iron vessels, easily portable, and our houses and drawing-rooms may now be illuminated by lamps that never need snuffing, sputter no grease, spoil no clothes, make no dirt, and never give a single spark. They may be carried about without danger, and if turned over or let fall, neither spill oil nor tallow. In general, they are not yet adopted, because people adhere to old practices and hate novelties; but ultimately they will come into use, and we shall be saved both dirt and trouble, and risks of fire will be diminished. In the lamps with which the London portable gas company engage to supply their customers, the gas is compressed into one-thirty-second of its usual volume.

It has been customary to consume oil gas with the same sort of burners as coal gas, which causes a considerable waste, and gives rise to a mistaken idea of the quantity of light given out by each gas. The argand burner, which admits the gas through a number of small holes, is the best species for perfect combustion, but, which would hardly have been imagined, it is found that these holes should be nearer together and smaller for oil gas than for coal gas. In any case they should be only so far apart that the flame from each should just coalesce with that from the next. The gas produced from oil contains more carbone than that from coal; the light is in proportion to the quantity of carbone, and the same sized holes which completely consume the carbone of the coal gas do not burn all that of the oil gas. It is, consequently, necessary that burners for oil gas should be made with smaller holes, and these holes should be closer together than those for coal gas. Hence oil gas is unfit for street lamps, as it is much more liable to be blown out by the wind.

The illuminating power of oil and coal gas has, however, been differently stated by different persons. According to some, the power of the oil gas is as three and a half times that of the coal gas; whilst, according to others, it is only two, and even not so great. On this question, however, turns one which is of very great importance, whether oil or coal gas works are most advantageous. Dr. Fyfe, in a paper in the Edinburgh Journal, first throws doubts on some experiments of Mr. Ricardo's and of other gentlemen, on account of their having been incorrectly made, while he seems disposed to admit the accuracy of the experiments of Messrs. Herepath and Rootsey, which do not give

so high an illuminating power to oil gas. Mr. Dewey's experiments, published in the Annals of Philosophy, and which showed a great degree of illuminating power in oil gas, were made, it appears, as well as some other experiments, with coal gas of a very small specific gravity, only 406, and Dr. Fyfe contends, that the illuminating power of both gases, after being properly purified, is in proportion to their specific gravity. The oil gas Mr. Dewey used was 939, which is very good, and if a good oil gas is only three and a half times superior to a very inferior coal gas, its superiority must be much reduced when brought into competition with the latter when of an equal good quality.

Dr. Henry proposed to ascertain the illuminating power of each gas by the quantity of oxygen necessary for its combustion, and tried by this test he obtained the following results:

| One hundred volumes of coal gas, of the specific gravity, | took of oxygen |
|---|---|
| 345 | 78 |
| 500 | 166 |
| 620 | 194 |
| 630 | 196 |
| 650 | 274 |
| **One hundred volumes of oil gas of the specific gravity,** | **took of oxygen** |
| 464 | 116 |
| 590 | 178 |
| 753 | 220 |
| 906 | 260 |

From this it appears that the best oil gas is to the worst coal gas, as three and a half to one, while the best of both stand in the relation to one another of 26 to 21.

On the theory that the olefiant gas contained in both is the principal source of light, as this gas may be condensed by chlorine, Dr. Fyfe proposes the condensation as a measure of the illuminating power of each. The mixture, however, must be excluded from the light, to prevent any action on the carburetted hydrogen.

The following method for trying this experiment is proposed by Dr. Fyfe. A graduated jar, inverted in a water trough, must be filled with fifty measures of the gas, fifty measures more of chlorine must then be introduced, the tube being covered with a paper shade, to prevent any action on the other gases. In the course of from ten to fifteen minutes, the condensation will be completed, and as the chlorine and olefiant gases combine in equal proportions, the diminution in the mixture will indicate correctly the quality of olefiant gas in the gas subjected to trial.

This experiment, in Dr. Fyfe's opinion, promised to be an accurate mode of ascertaining the comparative illuminating powers, and by this method he has found the oil gas, prepared in Edinburgh, to be to the coal gas, as thirty-one to seventeen, or nearly eighteen to ten. Dr. Fyfe admits that the other con-

stituents of both gases, possess some illuminating powers, and unless the proportion of these other ingredients are the same in both, and, consequently, his method is only an approximation to the real proportions; but he suspects coal gas will be found to possess, or, at least, may be made in general to possess, about half the illuminating power of that from oil. He has found this to be the case with those made in Edinburgh, by producing the same quantity of light, and marking the quantity of gas consumed.

## SPECIFIC GRAVITY.

The apparatus for determining the densities or specific gravities of bodies is very simple, but of the greatest use in determining the proper strength of the solvents to be employed in processes, or the time when operations are to be stopped; as also for investigating the purity of substances.

### *Hydrostatical Balance.*

For solid bodies, or gross fluids, the hydrostatical method of determining specific gravities is the best: the balances used for this purpose must be very good, and one of their scales made to take off, and have its place supplied by a piece of thick wire, or a cylindrical rod, with a hook at each end, which is of sufficient weight to counterpoise the scale that is left at the other end of the beam.

The first consideration is the apparatus to enable the chemist to weigh the substance first in the air, and then when sunk under water. This apparatus may be either a single horsehair or fine silver wire for such solid bodies as can be supported by tying them to it; or a net of the same materials for globular bodies; or a small glass bucket for powders, quicksilver, or other heavy liquids that remain at the bottom when put into water, and do not dissolve in it.

The apparatus being determined, and fixed to the hook of the balance, is to be counterpoised and the weight noted, the subject to be examined is then added, and exactly weighed. The difference between their weights is of course the weight of the substance in air.

A tumbler, or other vessel, of distilled, or rain water, is then brought under the apparatus, and the substance sunk in the water. If it is apt to imbibe that fluid, it is left in the water for some time, and then the water being removed, the substance is wiped, weighed again, and the quantity of water absorbed noted.

The substance is then weighed while under water, care being taken that no bubbles of air adhere to its surface, nor to

any part of the apparatus, which might buoy them up and render the weight false.

Finally, the substance being removed, the suspending apparatus used is counterpoised while under water to the same depth as before; and its weight noted.

The difference of these two last weights is the weight of the substance in water.

Now, as substances weighed in any liquid lose therein the weight equal to that of the liquid whose room they occupy, it follows that the difference between the weight in air and that in water, is, so far as is sufficient for practical uses, the weight of the volume, bulk, or cubic content of the water displaced by the substance: and, consequently, the ratio or proportion between the weight of the substance itself in air and that of the water it displaces, when weighed in water, shows the proportion of its relative weight or specific gravity in respect to that of an equal bulk of water.

Thus taking Mr. Boyle's example,—

Weight of a piece of marble in grains, 1169.

Weight, when under water, in grains, 738.

Loss of weight, being the volume or bulk of the piece of marble, in grain-measures of water, 431.

Then as 1169 is to 431, so is the specific gravity of marble to that of water; and of course, as it is usual to consider the specific weight of water as a standard, and call it unity, or 1, the proportion will be, as 431 is to 1169, so is 1 to a fourth number sought, whence as unity does not multiply, by simply dividing 1169 by 431, the required number is found, namely, 2.712, which is the specific gravity of the specimen under examination.

But of the solid absorbed water, then it is plain that although the preceding mode of calculation will give the apparent specific gravity, yet, in order to know the specific gravity of the solid parts of the body which do not admit water, it must be considered that the bulk of the water displaced, as measured by its weight, is not merely that lost on weighing the body in water, but only the difference between that loss and the weight of water it absorbed.

| | | |
|---|---|---|
| Weight of a dry piece of free-stone, | *a*, | 1000, in grains. |
| Weight after soaking some time in water, | | 1050 |
| Weight of water absorbed, | *b*, | 50 |
| Weight when under water, | | 460 |
| Loss of weight, being the volume of the water displaced, in grain-measures, | *c*, | 540 |
| Apparent specific gravity, produced by dividing, *a*, 1000 by *c*, 540, is | | 1.801 |
| Difference between the loss of weight, *c*, and the quantity absorbed, *b*, | *d*, | 490 |
| Real specific gravity, produced by dividing, *a*, 1000 by, *d*, 90, is | | 2.040 |

If the solid is lighter than water, and does not dissolve in it, the apparatus must have a heavy body attached to it to make the subject of the experiment sink in the water.

The specific gravity of liquids is determined hydrostatically by weighing a convenient solid body, that is not soluble either in water or the liquid, as a piece of glass, first in water and then in the liquid whose specific gravity is sought. For if the loss of weight in water be divided by the loss of weight in the liquid under examination, the quotient will be the specific gravity of the latter.

If the solid body to be examined is soluble in water, it must be weighed first in air, and then in some liquid which does not dissolve it, and its specific gravity determined in respect to this liquid. The specific gravity of that identical parcel of liquid must then be determined as just mentioned, and then the two specific gravities, namely, that of the solid in respect to the liquid, and that of the liquid itself in respect to water being multiplied together, the product will be the specific gravity of the solid in respect to water: for as the specific gravity of liquid used, is to that of water, so is the specific gravity of the solid in relation to that liquid, to its specific gravity in relation to water.

In all hydrostatical experiments, the temperature of the liquid, and of the air, as also the atmospheric pressure, as determined by the barometer, should be recorded; and as far as possible, the trials should be made at a uniform temperature and pressure, as a variation in these elements will make a very sensible variation in the determination of the specific gravity if attempted to be taken to any nicety.

It is indeed true, that it is possible to reduce the specific gravities taken at any temperature and pressure to any other desired temperature and pressure, provided the expansion of the subjects under examination by heat are known or investigated; but the calculation is long, and the very sight of the algebraic formulas, given by mathematical writers for this purpose, would appal a very great majority of practical chemists.

There are some other propositions relating to specific gravity which require to be mentioned.

If the weight of any body be divided by its specific gravity in relation to water as unity, the quotient will be the weight of a quantity of water equal to it in bulk; and, therefore, if this quotient be again divided by the weight of water which any assigned measure will contain, this second quotient will be the measurement of the body in that particular measure, however irregular may be its figure, or however difficult it might otherwise be to measure it.

If the bulk, volume, or admeasurement of any body be ex-

pressed by the weight of water which is equivalent to it, then this weight of water being multiplied by the specific gravity of the body in relation to water as unity, will give the weight of the body, supposing that a person has not the conveniency or power of weighing it.

When two bodies are chemically combined with one another, the bulk or volume of the compound is not equal to that of their joint bulks; being either greater or less; as is shown in the familiar experiment of gradually adding tea-spoon-fulls of salt or sugar to a wine-glass of water, which is so far from running over, that it actually fills the glass less than before the addition of the salt or sugar, so that the specific gravity of the compound is greater or less than the mean, as the compound either contracts or expands by the union.

The amount of the expansion or contraction is calculated in this manner, taking for an example, an experiment of Mr. Hatchett.

He melted eighteen pennyweights ten grains of gold with one pennyweight ten grains of copper, and found the specific gravity of the alloy to be 17.157.

Now, the weight of the gold, 442 grains, being divided by its specific gravity 19.172, gives for its bulk or volume twenty-three grain-measures of water .05. And in like manner the weight of the copper, thirty-four grains, being divided by its specific gravity, 8.895, gives for its bulk, or volume, four grain-measures of water .27. So that the joint bulk was twenty-seven grain-measures of water .32—The weight of the mixed metals, 480 grains divided by its specific gravity 17.157, gives for its bulk or volume twenty-seven grain-measures of water .98; so that an expansion of .66 of a grain-measure of water, or 66-2732th, of the whole mass, being rather more than the 1-41th part, took place in this alloy.

If instead of the mean volume, the mean specific gravity that any mixture ought to have, supposing no expansion or contraction was to take place, is desired, it may be found by dividing the sum of the weights of the ingredients, in the above experiment, 480 grains, by the sum of the volumes, 27 grain measures .32, the quotient 17.569 is the specific gravity sought, but the comparison of this calculated specific gravity with that found by experiment, namely, 17.157, does not, at least to mere practical men, give so clear an idea of the expansion or contraction occurring in the admixture of the two bodies, as the quotation of the volumes.

*Statical Examination of Gross Bodies.*

There is another mode of investigating the specific gravity of solid bodies and liquids, which is sometimes more convenient than that by the hydrostatic balance.

For this purpose, there is required a wide-mouthed stoppered bottle, that will admit the solid bodies intended to be examined to enter it; and whose stopper has a fine groove cut in it, by a file, along its length, that it may be put in when the bottle is filled to the brim with water, and allow the superfluous water to pass out by this groove.

In the examination of solid bodies, they are to be first weighed, and if they absorb water, weighed again in their wet state. The bottle is then weighed by itself, and afterwards being filled with water, a fresh weighing takes place; lastly, the solid is put into the water in the bottle, and the joint weight taken. From these elements the specific gravity of the solid, and its bulk or volume, is easily determined. For if the weight of the solid is divided by the weight of the water it displaces out of the bottle, the quotient is its specific gravity; and if the weight of the water it displaces be divided by the weight of water that is equivalent to any species of measure, the quotient will be the admeasurement of the body in that species of measure.

The examination of liquids in this method is more simple; the bottle is first to be weighed empty, then when filled with water, and, lastly, when filled with the liquid under examination; the weight of the liquid that the bottle holds being divided by the weight of the water, gives the specific gravity.

### *Homberg's Areometer.*

The areometer of Homberg, described and figured in the Mem. del Ac. Roy. des Sc. for 1699, is still the best instrument of this kind, for the examination of liquids.

It is a bottle of very thin glass, with two necks, as shown in fig. 64, which are drawn out to such fineness, that a single drop of water may occupy the length of about half an inch in them. One of these necks is longer than the other, and dilated at the mouth like a small funnel; and each of them has a fine mark made nearly on a level with the top of the shortest.

The weight of water that this areometer holds being ascertained and noted down, then when it is filled with any other liquid, up to the marks, and the weight of the liquid ascertained, by dividing the weight of the liquid by the weight of the water, the quotient is the specific gravity of the liquid.

The exact quantity of water, or liquid, to fill it to the two marks, is adjusted by adding, or taking out, a small quantity by the point of a fine hog's bristle, or, in some very corrosive liquids, by a fine thread of glass.

The use of the second short pipe is to let the air escape, as the liquid is poured into the areometer by the long pipe.

### *Thousand-grain Bottle.*

For conducting this experiment with greater facility, a specific gravity bottle is now usually sold under the name of a "thousand-grain bottle," together with a weight which is an exact counterpoise for it when filled with distilled water at 60° Fahr.

It is a glass bottle with a slender neck, and is furnished with a ground conical stopper, in the side of which there is a notch, or indentation, by which the operator is enabled to put in the stopper after the vessel has been completely filled, the redundant fluid escaping through this groove. Unless such a con-

trivance were adopted, it would be difficult to fill a bottle with liquid without enclosing some bubbles of air.

This instrument, consequently, does not require the aid of any computation, but is simply filled with the fluid to be examined, and placed in one scale of the balance, while its counterpoise is placed in the other. If the contained fluid be lighter than water, it will appear deficient in weight, and as many grains must be added to the scale that contains it, as may be sufficient to restore the balance. This shows at once, that the specific gravity of the fluid in question is less than the standard, and, consequently, that it must be expressed by a fractional number; but should the fluid be heavier than water, the bottle will preponderate, and weights must be put in the opposite scale, when their amount must be added to that of the standard.

For example, if the bottle were filled with sulphuric ether, it would require 261 grains to be placed in the same scale to restore the balance, and, consequently, its specific gravity would be expressed thus, 0,739. Had it been filled with sea-water, which is rather more dense than that which is distilled, 26 hundredths, or rather better than a quarter of a grain, must have been added in the opposite scale, and which, as already explained, must be added to the standard, 1.000, to express the specific gravity of such water, which would be stated thus, 1.026. Sulphuric acid, again, being still heavier, would, in like manner, require 875 grains, and must accordingly be expressed as 1.875.

### *Cubical-inch Bottle.*

Another very similar contrivance is that called the cubic-inch bottle. This is a bottle which exactly holds a cubic inch, when the stopper is in its proper place, and is very convenient, and frequently used for readily ascertaining the absolute gravity in a cubic inch of different liquids.

These two last contrivances are, however, expensive, very seldom exact, and more adapted for amateurs than real practical chemists.

Dr. Richard Davies, in Phil. Trans. for 1748, has given a large collection of the specific gravities of different bodies, from various authors, and partly from his own trials on a collection of materia medica made by Signor Vigani, and preserved in the library of Queen's college, Camb.

Brisson has since extended this list, in his Pesanteur des Corps.

Mr. Heidinger is publishing a very accurate list of the specific gravity of mineral substances, for the purpose of using it as a characteristic of them.

All tables of specific gravities ought to be accompanied with the cubic expansion of the several substances by heat, as this is absolutely necessary to reduce the expressions from one temperature to another.

### *Baumé's Hydrometer for Salts.*

There are two hydrometers which were brought into use by Baumé, a chemical manufacturer at Paris, which are of easy construction, a point to which Baumé was particularly attentive in all his apparatus.

Fig. 65, represents the hydrometer for saline fluids, which is adjusted for use by Baumé in the following way:—The instrument having a piece of paper on which the scale is to be marked put in the stem, is first immersed in pure water at a temperature of 18.75° Reaum. equal to about 50° Fahr. and loaded with quicksilver dropped into the lower bulb till it sinks so low that only the very top of the stem was out of water, and which point was previously marked both on the paper and the stem as the 0 of the scale. The instrument is then removed to a solution of common salt, containing fifteen parts by weight of salt to eighty-five parts of water, and the height to which it floats marked on the stem as 15° of the scale. The paper being then taken out, the interval between these two points of immersion is marked on the scale as 15°, and it is extended to 75°, or any required number, merely by marking them off with compasses. The paper with the scale is then replaced in them, fixed in its place

with a very minute piece of soft wax, and the end of the stem sealed at the lamp.

Baumé considered, therefore, that every degree of the instrument indicated a density of liquid equal to that of a solution of common salt, in which the number of parts of salt in one hundred parts, by weight of the solution, was equal to the same number on the scale at which the instrument floated.

But as the diameter of the stem is seldom equal throughout, he proposes to remedy the incorrectness produced by this circumstance, where greater accuracy is required, by immersing the instrument successively in solutions containing 5, 10, 15. per cent. of salt, and making these points as 5, 10, 15, &c. on the scale, or, to be still more accurate, all the individual degrees may be found by actual experiment.

In fact, even where the stem of the instrument is perfectly cylindrical, this would be the only way to ensure perfect accuracy, as a division of equal distances on the scale would not precisely correspond with an equal increase of the quantity of salt in the solution. But this accuracy is hardly necessary, as the use of a hydrometer is at the best an imperfect approximation to the true specific gravity.

The scale of this instrument does not properly extend higher than about 30°, as this is the point of saturation of water with salt, but it may be lengthened at pleasure by marking off equal distances on the scale.

The following table of correspondence between Baumé's hydrometer for salts, and the actual expression of specific gravity, has been calculated by Drs. Brugmans, Driessen, Vrolik, and Deiman, the committee for compiling the Pharmacopœia Batava. The temperature of the liquor being from 56 to 60° of Fahrenheit's scale; for as no two of these hydrometers are found to agree accurately together, although they are sufficient for ordinary use, there is no occasion to be more particular in noting the temperature.

| Baumé. | Specific gravity. | Baumé. | Specific gravity. |
|---|---|---|---|
| 0 | 1.000 | 32 | 1.286 |
| 1 | 1.007 | 33 | 1.298 |
| 2 | 1.014 | 34 | 1.309 |
| 3 | 1.022 | 35 | 1.321 |
| 4 | 1.029 | 36 | 1.334 |
| 5 | 1.036 | 37 | 1.346 |
| 6 | 1.044 | 38 | 1.359 |
| 7 | 1.052 | 39 | 1.372 |
| 8 | 1.060 | 40 | 1.384 |
| 9 | 1.067 | 41 | 1.398 |
| 10 | 1.075 | 42 | 1.412 |
| 11 | 1.083 | 43 | 1.426 |
| 12 | 1.091 | 44 | 1.440 |
| 13 | 1.100 | 45 | 1.454 |
| 14 | 1.108 | 46 | 1.470 |
| 15 | 1.116 | 47 | 1.485 |
| 16 | 1.125 | 48 | 1.501 |
| 17 | 1.134 | 49 | 1.526 |
| 18 | 1.143 | 50 | 1.532 |
| 19 | 1.152 | 51 | 1.549 |
| 20 | 1.161 | 52 | 1.566 |
| 21 | 1.171 | 53 | 1.583 |
| 22 | 1.180 | 54 | 1.601 |
| 23 | 1.190 | 55 | 1.618 |
| 24 | 1.199 | 56 | 1.637 |
| 25 | 1.210 | 57 | 1.656 |
| 26 | 1.221 | 58 | 1.676 |
| 27 | 1.231 | 59 | 1.695 |
| 28 | 1.242 | 60 | 1.714 |
| 29 | 1.252 | 61 | 1.736 |
| 30 | 1.261 | 62 | 1.758 |
| 31 | 1.275 | 63 | 1.779 |

| Baumé. | Specific gravity. | Baumé. | Specific gravity. |
|---|---|---|---|
| 64 | 1.801 | 70 | 1.946 |
| 65 | 1.823 | 71 | 1.974 |
| 66 | 1.847 | 72 | 2.002 |
| 67 | 1.872 | 73 | 2.031 |
| 68 | 1.897 | 74 | 2.059 |
| 69 | 1.921 | 75 | 2.087 |

## *Baumé's Hydrometer for Spirit.*

The hydrometer for spirit, of Baumé, is constructed exactly on the same principle as the hydrometer for salts, and the mode of graduation is also the same; that is, by solution of salt, and not by mixtures of spirit and water of different densities.

Fig. 66, represents this hydrometer, in which the zero is placed not at the top of the stem, and at the point to which the stem sinks in distilled waters, but at the bottom of the stem, and at the point to which it sinks in a mixture of ten parts of salt and ninety of water. The interval between this point and that of distilled water is divided in the scale into 10 degrees, and this scale is continued upwards by measuring simply equal portions by the compass. The tenth degree of the spirit hydrometer corresponds with the 0 of the hydrometer for salts.

The correspondence between Baumé's hydrometer for spirit and the real expression of specific gravity has also been calculated by Drs. Brugmans, Driessen, Vrolik, and Deiman, the committee for compiling the Pharmacopœia Batava. The temperature of the liquor being from 56 to 60° of Fahrenheit's scale, for as no two of these hydrometers are found to agree accurately together, although they are sufficient for ordinary use, there is no occasion to be more particular in noting the temperature.

| | | | | | |
|---|---|---|---|---|---|
| 50 | 0.782 | 36 | 0.847 | 22 | 0.923 |
| 49 | 0.787 | 35 | 0.852 | 21 | 0.929 |
| 48 | 0.792 | 34 | 0.858 | 20 | 0.935 |
| 47 | 0.796 | 33 | 0.863 | 19 | 0.941 |
| 46 | 0.800 | 32 | 0.868 | 18 | 0.948 |
| 45 | 0.805 | 31 | 0.873 | 17 | 0.954 |
| 44 | 0.810 | 30 | 0.878 | 16 | 0.961 |
| 43 | 0.814 | 29 | 0.884 | 15 | 0.967 |
| 42 | 0.820 | 28 | 0.889 | 14 | 0.974 |
| 41 | 0.823 | 27 | 0.895 | 13 | 0.980 |
| 40 | 0.828 | 26 | 0.900 | 12 | 0.987 |
| 39 | 0.832 | 25 | 0.906 | 11 | 0.993 |
| 38 | 0.837 | 24 | 0.911 | 10 | 1.000 |
| 37 | 0.842 | 23 | 0.917 | | |

## *Fahrenheit's Hydrometer.*

In the preceding hydrometers, the investigation is conducted by simply observing the depth to which the instruments sink in the liquid that is tried.

Fahrenheit, in the Phil. Trans. for 1724, introduced another class of them, which are always sunk to a mark made on their stem, by means of weights, and which are susceptible of much greater accuracy.

Fig. 67, represents Fahrenheit's hydrometer, which consists of two hollow glass balls, *a*, *b*, joined by a long cylindrical pipe, *c*; the upper larger ball, *a*, has at its top a shorter pipe, *d*, on which a mark, *e*, is made about the middle of its height; this pipe is spread out at top like a funnel. The hydrometer is bal-

Fig. 64.

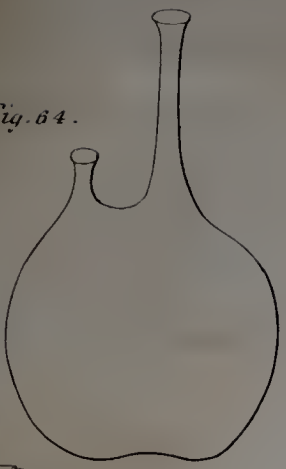


Fig. 68.

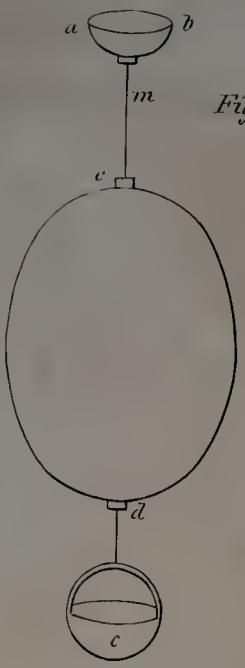



Fig. 69.

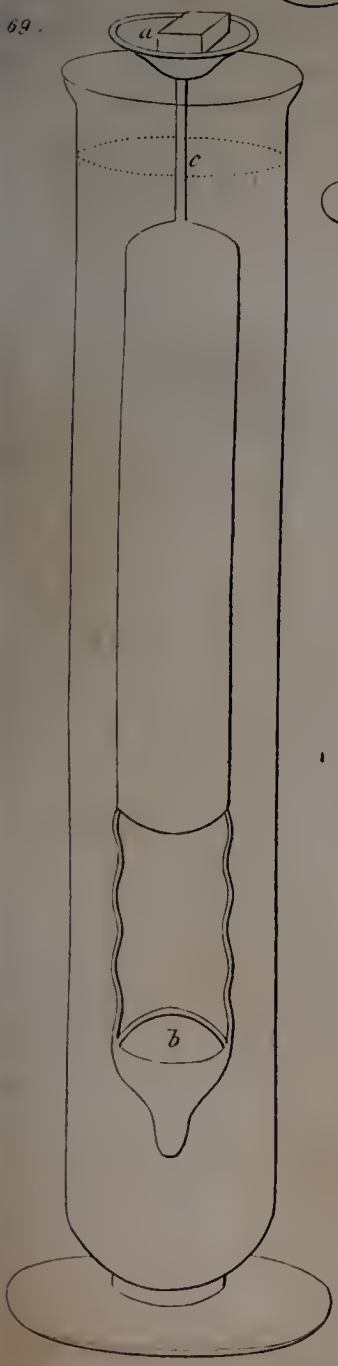



Fig. 67.

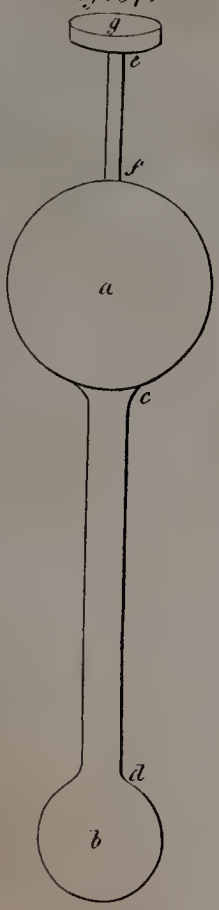



Fig. 66.

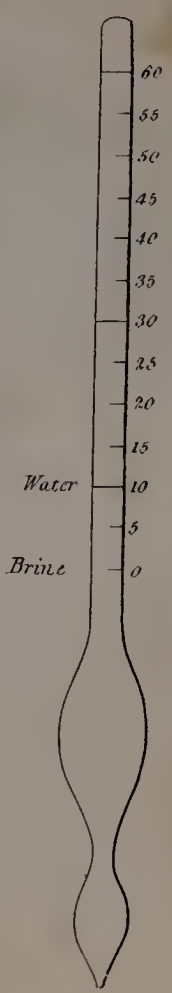
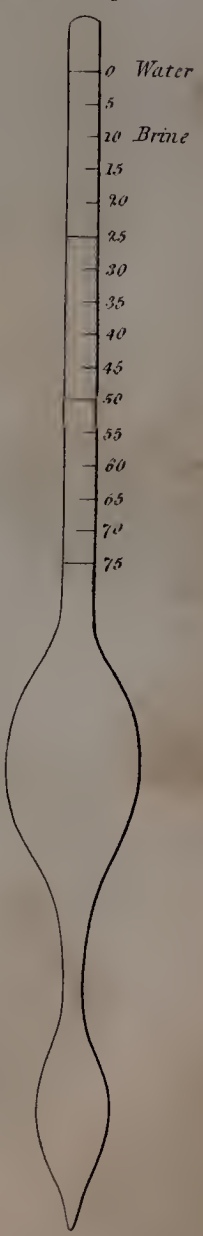



Fig. 65.



lasted by adding a little quicksilver, so as to cause it to sink in spirit of wine nearly to the mark; and it is then hermetically sealed, and carefully weighed.

Thus prepared it is fitted for the investigation of the specific gravity of liquids. For which purpose, let it float on distilled water at any assigned temperature, and add weights to sink it to the mark: the weight, added to that of the instrument, is the weight of the water which the instrument displaces. Proceeding in the like manner to find the weight of any other liquid that the instrument displaces, this latter weight, divided by that of the water, gives the specific gravity.

M. Deparcieux used a hydrometer of this kind to investigate the specific gravity of the waters of a number of springs in France: but in order to increase its sensibility he augmented the size.

His bulb was a bottle, the bottom of which was left convex to prevent the air from lodging below. This bottle was about eight inches long and two in diameter; and was ballasted with shot. It was stopped by a well-varnished cork, in which was inserted a brass wire about thirty inches long and one-twelfth of an inch in diameter; to the top of which was fixed a small cup for the weights. The whole instrument weighed about twenty-three French ounces one-fourth.

A vessel of tin-plate, about three feet long and three inches in diameter, was used to hold the waters examined, to the edge of which was attached a rule divided into inches and parts.

The instrument was so sensible that a single grain placed in the cup made it descend half an inch, or one-seventeen thousand four hundred and twenty-eighth part of the bulk of the water displaced.

## *Nicholson's Hydrometer.*

The hydrometer invented by the late Mr. Nicholson, is an alteration of Fahrenheit's hydrometer, to render it capable of ascertaining the specific gravities of solids as well as of liquids.

Fig. 68, represents this instrument; *a*, is a hollow ball of brass or copper; *c*, is a dish affixed to the ball by a short slender stem, *d*; *c*, is another dish affixed to the opposite side of the ball, by a kind of stirrup. The stem, *d*, is best made of hardened steel, one-fortieth of an inch in diameter, and the dish, *c*, is so heavy as, in all cases, to keep the stem upright when the instrument is made to float in any liquid. The ball is so large as to require the addition of one or two ounces in the upper dish, *b*, to sink it in distilled water, at the temperature of 60° of Fahrenheit's thermometer, so that the surface shall intersect the middle of the stem, *d*; and let both this weight and that of the instrument itself be accurately determined.

If it be required to find the specific gravity of any liquid which has no action upon the metal, immerse the instrument therein, and by placing weights in the dish, *b*, cause it to float, so that the middle of its stem, *d*, shall be cut by the surface of the fluid. Then as the known weight of the instrument added to the weight required to sink it in water, is to the same known weight added to the weights used in producing the last equilibrium, so is the weight of a quantity of distilled water displaced by the floating instrument to the weight of an equal bulk of the fluid under consideration. And consequently, the first weight divided by the second, will give the specific gravity, as in Fahrenheit's instrument.

Again, if it be required to find the specific gravity of a solid body weighing less than the weight required to sink the instrument in water, place the hydrometer in distilled water, and the body in the dish, *b*, then make the adjustment by adding weights in the same dish; subtract this weight from that required to sink it in water, and the remainder will be the weight of the body in air. Place now the body, in the lower dish, *c*, and add weight in the upper dish, *b*, till the adjustment is again obtained. The weight last added will be the loss the solid sustains by immersion, and is the weight of an equal bulk of water. Consequently the specific gravity of the solid, compared with water, is found by dividing its weight in air, by the loss it sustains by immersion.

As the cylindrical stem of this instrument is only one-fortieth of an inch in diameter, the instrument will rise or fall nearly one inch by the subtraction or addition of one-tenth of a grain. It will, therefore, indicate changes in weight less than one-twentieth of a grain, or one-sixty-two thousandth of the whole; which will give the specific gravities correct to five places of figures.

M. Charles added to this hydrometer a contrivance for inverting the lower basin by a hook to its bottom, by which it hangs, when the solid whose specific gravity is required is lighter than water. In this case, the basin is inverted, and the solid presses upwards against its bottom, and, of course, the hydrometer requires less weight to sink it.

Another person, for the purpose of investigating the specific gravities of light woods, added a spike to the fork of a stirrup; on which they may be stuck.

### *Guyton de Morveau's Gravimeter.*

Guyton's gravimeter is another alteration by the celebrated chemist, M. Guyton de Morveau, of Fahrenheit's hydrometer; it is made of glass, and carries two basins, like the hydrometer of Nicholson. The bulb is cylindrical, and is connected with the upper basin by a slender stem, in the middle of which is the fixed point of immersion. The lower basin, which terminates in a point, contains the ballast, and is attached to the cylinder by two branches. The cylinder in M. Morveau's own instrument was six inches .85 in length, and 71 hundredths of an inch in diameter. The upper basin carried an additional weight of 115 grains.

To this apparatus M. Guyton added another piece, called the ballast piece, which is a lump of glass equal to the additional weight of 115 grains, added to the weight of the volume of water displaced by this ballast piece. This ballast piece is always placed in the lower basin when it is used; and, of course, the gravimeter will sink it to the same mark on the stem, whether it is loaded with the constant weight of 115 grains in the upper basin, or with the ballast piece in the lower basin.

Fig. 69, represents the gravimeter; *a*, the lower basin; *b*, the upper basin; *c*, the point of immersion, marked on a thin piece of glass in the inside of the stem marked *x;* the piece called the ballast piece, which is placed in the lower basin, *a*, when experiments are made on fluids of greater density than water. The gravimeter is placed in a cylindric vessel filled with water, in which it floats immersed to the mark *c*, by means of the additional constant weight, *d*. It is convenient to choose a vessel of such a depth that the instrument may be at liberty to float at the level of the mark, or even beneath it, without its being possible that the bottom of the upper basin should ever descend to the surface of the water.

A paper is pasted on the inner surface of the cover of the case in which this instrument, from its fragility, must always be kept, to show the weight of the gravimeter with or without the additional ballast piece and the volume of water it displaces in either case; as these are often required to be accurately known.

This instrument may be used for solids or fluids. It is, in fact, the hydrometer of Nicholson, from which it differs in no respect, except being made of glass. The only condition requisite for using it will be, as in his instrument, that the absolute weight of the body to be examined shall be rather less than the constant additional weight, which, in Morveau's own instrument, was 115 grains.

For liquids of less specific gravity than water, the instrument, without the additional weight above, weighed about 459 grains when of the dimensions

before laid down. It would be easy to alter this weight to the utmost accuracy, if it were requisite. We have, therefore, the range of one-fifth of buoyancy, and, consequently, the means of ascertaining all the intermediate densities, from water to the most highly rectified spirit of wine, which is known to bear, in this respect, the ratio of eight to ten with regard to water.

When liquids of greater specific gravity than water are to be tried, the constant weight being applied below by means of the ballast piece, which, in M. Morveau's instrument, weighed about 138 grains, the instrument can receive in the upper basin more than four times the usual additional weight, without losing the equilibrium of its vertical position. In this state it is capable of showing the specific gravity of the most concentrated acids.

It possesses another property common to the instrument of Nicholson, namely, that it may be used as a balance to determine the absolute weight of such bodies as do not exceed its additional load.

The object of this instrument is to ascertain, 1st. The specific gravities of solids, whose absolute weight is less than 115 grains; 2d. Of liquids inferior to water in specific gravity; 3d. Of liquids of greater specific gravity than water; 4th. The absolute weight of bodies below 115 grains; and, 5th. The rarefaction and condensation of water in proportion to its bulk, the purity of water being previously known.

In order to find the specific gravity of any solid by this instrument, place the solid in the upper basin, and add weights till the instrument sink to the fixed point of immersion in water or any other convenient liquid. Subtract these weights from the constant weight of 115 grains, and the remainder is the absolute weight of the solid. Multiply this by the specific gravity of the fluid, and note the product. Place the solid in the lower basin and add weights in the upper basin till the instrument sink to a fixed point of immersion; and subtracting these additional weights from the additional weights when the body was in the upper basin, the remainder will be the loss of weight by immersion. Divide the reserved product by this loss of weight, and the quotient will be the specific gravity of the solid with regard to the specific gravity of the liquid in which it is weighed.

In order to find the specific gravity of a fluid, first immerse the gravimeter in the fluid, and having observed the weight which is necessary to sink it to the fixed point of immersion, add this weight to that of the gravimeter; then to the weight required to sink it in distilled water, add also the weight of the gravimeter. Divide the first sum by the second, and the quotient will be the specific gravity of the fluid.

The additional or ballast piece to be placed in the lower basin when liquids heavier than water are examined, requires some attention to make it perfectly agree with the constant upper weight as to the immersion of the instrument. But this object may, by careful adjustment, be attained with the utmost certainty and accuracy.

The glass is first brought to the proper form by grinding, and afterwards carefully diminished until, when placed in the lower basin of the instrument, its immersion in distilled water at the intended degrees of temperature and pressure shall be exactly the same as when the instrument is floated in the same liquid with its constant additional weight of 115 grains in the upper basin only.

By this means there is a certainty of acquiring the utmost degree of precision at first trial; because the whole process is reduced to the mere adjustment of a weight.

### *Areometrical Beads.*

It has been long customary to use the floating of a new-laid egg, or of a piece of amber, to ascertain when brines were boiled down sufficiently for crystallization.

The late Dr. Wilson, professor of astronomy in the University of Glasgow, proposed to measure the specific gravities of fluids by a series of small glass beads, or hollow balls, differing

from each other in specific gravity. When any of the beads are thrown into the fluid, all those that are heavier than the fluid sink to the bottom, while those that are lighter float upon the surface.

The areometrical beads have been brought to a very high degree of perfection by Mrs. Lovi. They are now used by many of the first distillers and practical chemists, and have been honoured with the highest approbation of some of the principal manufacturing chemists.

These beads are fitted up in boxes, containing different quantities, according to the purposes for which they are wanted; and they are always numbered to every two units in the third place of specific gravity; for example, 920, 922, 924, &c.

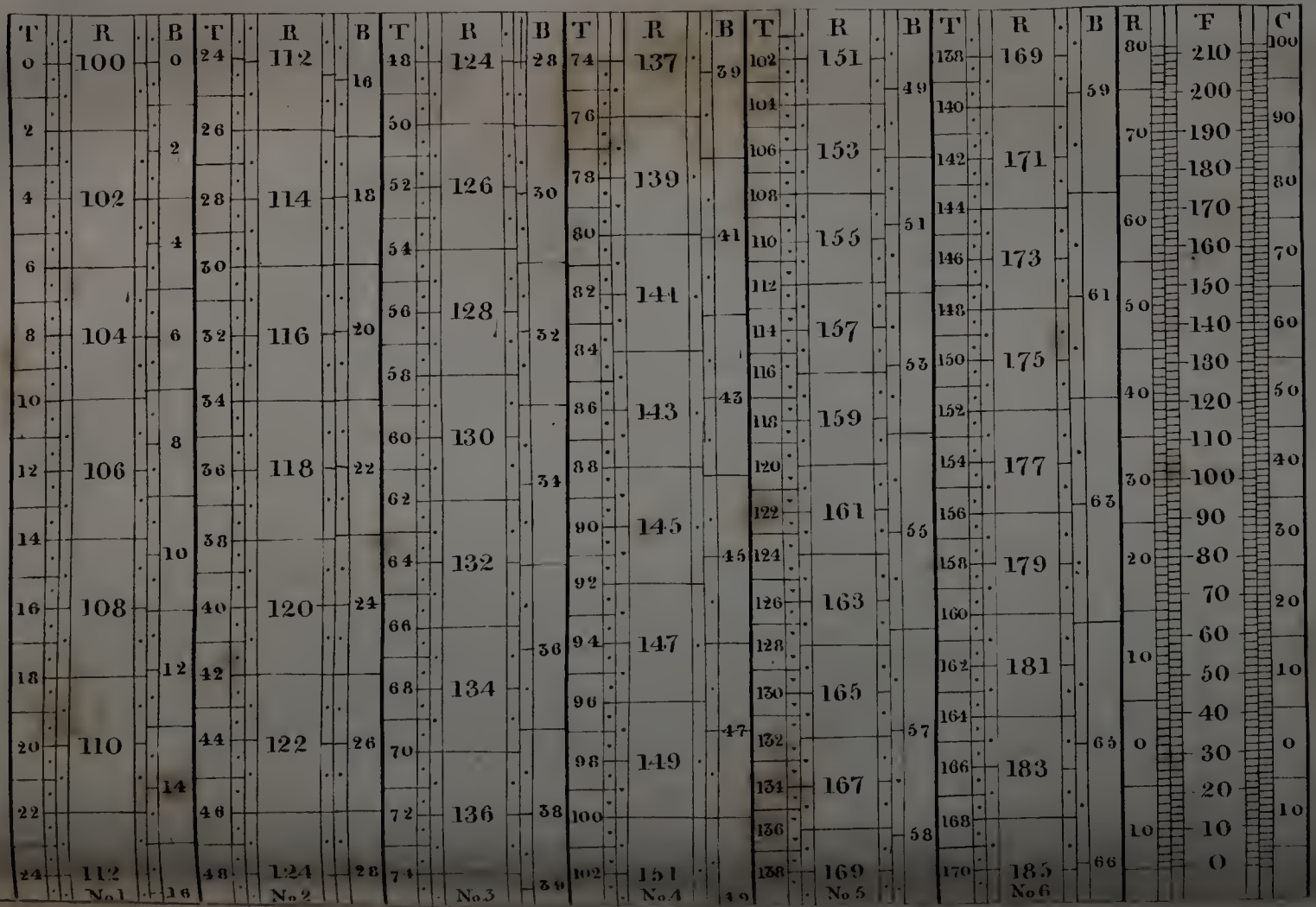
If they are required merely for spirituous liquors, thirty beads will be sufficient; but if they are required for all fluids, from ether to the most concentrated sulphuric acid, three hundred at least will be required. As these beads are marked with their respective specific gravities, we have only to throw a parcel of them into the fluid till we find the one that stands in the middle of the liquid, without either rising to the top, or sinking to the bottom. The number marked upon this bead will indicate the specific gravity of the fluid. The beads are accompanied by a sliding rule, and a thermometer for making the corrections for differences of temperature, and for finding the strength of the spirits, in the language of spirit dealers and excise officers.

The superiority of this hydrometer to every other is very great, but it is proportionably expensive. If, however, the ordinary hydrometer meet with any accident, it is incapable of being repaired; but if any of the areometrical beads are broken, they can easily be replaced, and the specific gravity may be determined with sufficient accuracy, if one, or even two, beads of the series are destroyed.

In using these areometrical beads for the purpose of determining when saline solutions have been boiled down, or otherwise concentrated to a proper point, Mr. Loudon has adopted the use of two beads, one rather lighter than the proper specific gravity of the liquid when fit for use, and the other rather heavier. If both sink, the liquor is not yet brought to the proper point; and, on the other hand, if both float it is too strong: the proper strength being when one floats and the other remains at the bottom.

### [*Twedale's Hydrometer.*

This instrument is in form and principle the same as Baumé's hydrometer for salts, except in the graduation. It takes cognizance only of liquids whose specific gravity exceeds that of water. Its zero is water at 60°, and the space between that and 1.850 (formerly regarded as the specific gravity of concentrated sulphuric acid,) is divided into 170 equal parts. It is in almost universal use among the practical chemists and calico printers, and bleachers, of Lancashire, and throughout the north of England, Scotland, and Ireland; and on that account has been adopted in the articles on calico printing and bleaching, and several others in this work for facility of comparison with the experience and formulæ of English workmen and manufacturers. I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48 124 28
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170 185 75
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70 190 90
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60 160 80
150
50 140 70
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120 60
40 110 50
100
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20 70 30
60
10 50 20
40
0 30 10
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10 10 0
0

have said that the space between the specific gravity of water and 1.850 is divided into 170° or equal parts, but this is on the supposition that the stem is of an equal calibre throughout, which, however, is rarely the case and cannot be trusted; every degree, or, at least, every ten degrees, should be ascertained by actual experiment. The general methods of procedure for this purpose have already been explained.

*Rouchetti's Hydrometer.*

Mr. Rouchetti, a philosophical instrument maker of Manchester, has introduced another hydrometrical scale, which is a good deal used by the calico printers, and has the advantage of its indications being easily converted into either Twedale's, or the common scale now universally adopted by scientific men, which assumes water to be 1.000 at 60° Fahrenheit. He commences his graduation with 100, which he assumes to be the specific gravity of water, and divides the space between that and 1.1850, into 185 equal parts. If we multiply the two right hand figures by 2, the product will give the degrees on Twedale's scale; if we consider the two right hand figures on Twedale's scale as decimals, his column corresponds exactly with that, which reckons water as 1.000 except that it wants the third decimal figure, which is not required in the operations of the arts. The following table shows the correspondence between Twedale, Rouchetti, and Baumé's scales. The three last columns have no immediate connexion with this subject, but will be found convenient to the practical chemist, as showing the correspondences also in the indications of Reaumur, Fahrenheit's, and the Centigrade thermometers; the first in general use in France, the second in England and America, and the latter in Germany and the north of Europe.] See the appended Table.

## PULVERIZING APPARATUS.

Pounding is one of the most common methods of dividing solid substances into smaller particles. The chemist must therefore be provided with mortars of different kinds, glass, wood, iron, steel, marble, siliceous stones, and porcelain ware, with their respective pestles. The nature of the substance which the chemist has occasion to pound, must direct him in the choice of one mortar in preference to another. He must have glass mortars for rubbing together corrosive saline substances; while, for bruising succulent herbs, roots, and other recent vegetable substances, which do not require trituration, mortars made of box-wood, or oak, may be used.

It is scarcely necessary to observe, that in order that the matter may be properly subjected to the effect of the pestle, the bottom of mortars must be of a concave form, and the side

should neither be so inclined as not to allow the substance operated on to fall to the bottom, between each stroke of the pestle, nor so perpendicular as to collect it too much together, and to retard the operation.

The larger kinds of cast-iron mortars, commonly called laboratory mortars, are always provided with wooden covers, to prevent the finest and lightest parts from escaping, and to defend the operator from the effects of disagreeable or noxious substances. But these ends are more completely attained by tying a piece of pliable leather round the pestle and round the mouth of the mortar. It must be closely applied, and at the same time so large, as to admit the free motion of the pestle. In some instances it will be even necessary for the operator to cover his mouth and nostrils with a wet cloth, and to stand with his back to a current of air, that the very acrid particles which arise may be carried from him.

To lessen the manual labour, the pestle of large mortars is fastened to the end of a flexible wooden pole, which is fixed by its other end to the roof, in a horizontal position, by the elasticity of which the pestle is lifted up again to the proper height after the stroke is made; and the operator has only to direct and impel the downward stroke.

Steel mortars are used for breaking into smaller pieces, very hard but brittle substances, such as the hard stones, called gems: these mortars differ in their form from all the others, being cylindrical; and the pestle is of the same form, fitting very close, and when used struck by a hammer.

Bronze mortars, with iron pestles, are the best for general purposes; the toughness of the metal, and it not being liable to rust, rendering it superior to iron.

As to brass mortars and pestles, they are only fit to pound spices and sugar for kitchen use, where their bright gold-yellow colour renders them greater favourites than the bronze.

White marble mortars, with pestles of the same, are the best for powdering salts, as they preserve the whiteness of the powder: they are also the only mortars in which fine white emulsions can be made: but the same mortar or pestle ought not to be used for both purposes.

Dark-coloured marble mortars, with hard wooden pestles, are the best for beating together gummy and pasty substances, as they allow the operator to give a heavy stroke, without fear of breaking the mortar; and as these substances usually stain the marble, the mortars are rendered less disagreeable than when white marble is used.

Larger mortars of this kind, or even of wood, with wooden pestles, are employed for bruising pulpy vegetables, or beating them up with sugar, or similar substances.

Glass mortars, with glass pestles, can only be used for rubbing together powders, and dissolving them in cold liquids.

Wedgewood-ware mortars, with pestles of the same ware, are equally unfit for powdering hard bodies, but, from their roughness, are superior to glass for rubbing powders together, and allow hot liquids to be poured into them.

Agate mortars, with pestles of the same, are, of course, very small, and totally unfit for powdering; but they are used for grinding the hardest powders, such as those of stones for analysis, glasses for enamelling and glass painting, and the harder earthy and metallic colours for painters. The pestles of these mortars are sometimes fixed in a wooden handle, so as to resemble a hammer.

It should always be remembered, that when a very hard body is ground to powder, the friction wears the mortar as well as the substance pulverized; consequently, for delicate experiments, it is necessary to weigh the powder before and after the process, and to allow for the increase of weight by what has been abraded from the mortar.

Mortars, as will be seen hereafter, are still used on a very large scale in the mine-works, and my grandfather and father, who, for some time, were the only makers of flour of mustard seed in or near London, used numbers of them in a horse-mill, until a manufacturer at Staines began to grind it with stones, sometime about 1780; soon after which, the present compound powder, formed of mustard flour, capsicum, turmeric, salt, and wheat flour, was introduced in the place of the genuine mustard.

## FILTERING APPARATUS.

The most usual process for clarifying fluids consists in filtering them; but this operation cannot be performed without the aid of intermediate substances, the very minute pores of which suffer only the fluid to pass through them: an infinite variety of substances are used as instruments of filtration, paper, flannel, linen, earths, pounded glass, charcoal, porous stones, &c. all of which may be usefully employed.

### *Paper Filters.*

Paper is known to be a kind of web formed of vegetable fibres that have undergone various preparations. The particles of these fibres are intermingled in such a manner as to leave between them pores, the tenacity of which is always proportionate to the state in which the paste was at the moment it was converted into paper.

The great art is to choose paper, the pores of which have precisely the size requisite for admitting only the fluid that is to be filtered, but none of the particles that impair its transparency.

Two sorts of paper are met with which produce this effect, and though they are not always so perfect as might be desired, they are those which have hitherto been preferred, as having but little size in their composition. The one is white, the other is a kind of gray paper.

The liquids that have been filtered through white filtering paper, are always transparent; but it has the inconvenience of breaking very readily, and its pores are soon obstructed, so that the filtration goes on but slowly.

The gray paper can serve for a greater length of time to furnish also clear liquids, but as the size with which it has been manufactured, has not been so well purified as that of the white filtering paper, it always communicates to the liquids a disagreeable taste, which proceeds from the solution of the foreign substances contained in this paper. This is also the reason why certain fluids, such as whey, wine, spiritous compounds, and other potable liquids, that have been filtered through gray paper, have always a smell and a taste, which are easily recognised by an accurate taster. Hence it proceeds that, amongst these liquids, some are more susceptible of spoiling than when they have been filtered through white filtering paper.

The nature of the paper demands most attention when saline solutions are filtered. If gray paper is used, it often happens that a part of its substance is dissolved by their action, so that the filtered liquid is not so pure as we should wish to have it. This inconvenience, which is not so perceptible when white paper is used, may be still more diminished by the precaution of not employing filters till after they have previously been washed several times with boiling water. A chemist ought always to keep a store of filters washed in this manner.

M. Josse has remarked that whey, clarified and filtered through white paper, could be kept in good preservation for more than a fortnight, when filtered every day; which was not the case with the ordinary gray paper, even though previously washed.

By a diametrically opposite effect, other vegetable juices have been rendered transparent, and kept in good preservation, without passing into the acid state, by filtering them every day through gray paper; it has only been observed that their colour became more intense during the first days, and that they afterwards gradually became colourless.

In order that a filter of paper may produce its full effect, it is necessary that it should not adhere too closely to the funnel which supports it, otherwise the filtration would soon be interrupted. This inconvenience is avoided by folding it different ways, but as these folds soon become deranged, some prefer placing straw or glass tubes between the filter and the funnel, but the folds made in the filters, produce as much effect as the straw and tubes. Funnels grooved on their inner surface are very commonly used for this purpose.

There is a far superior contrivance which may be applied, as well to the greatest as smallest quantities. It is an earthen cullender, made of a size proportionate to the business intended to be performed by it, and very full of holes, which ought to be also of a larger bore, than in the sort intended for household purposes. The cullender of the largest size must not, however, exceed what a sheet of filtering paper will well cover; for any greater magnitude than that would become useless. With these must be had also a glass funnel, whose mouth is broader than the cullender, and a stand, by which the cullender may be supported over the funnel. Where this kind of filter is not used in the intention of purifying any liquid body, but for separating a sediment, or precipitated powder, from some superfluous fluid, or when the liquid is of an alkaline nature, a linen cloth, of the size of the paper, must also be procured, and placed under it. By this apparatus, all the ends of filtering may be answered with great ease and expedition.

Very large glass funnels next suit this purpose best, provided the paper be supported in the hollow of the funnel, with a little cotton lightly thrust into the hollow. But this method is much more precarious, as well as slower than the other; and the paper, if not good, or if used with fluids of a relaxing quality, is very subject to break during the operation, and thereby frustrate all that has been done.

When a very small quantity of precipitate is to be collected, and its weight

accurately determined, the paper being cut of a proper size, is held before the fire, and, when sufficiently heated, is rubbed with tallow, except a small round space in the centre, which is to form the point of the filter when folded. The filtration being finished, that part of the precipitate which has settled on the side of the filter, is washed down by a fine stream of water, or other proper liquid, from a funnel, or syringe, until the whole is collected at the point.

*Flannel Filters.*

Flannel filters are much in use; they are made in the form of a cone, the base of which is kept open by means of a hoop, which is afterwards fastened to a frame, or hook, with strings. This species of filter is termed the Hippocrates' sleeve; it is used for filtering spirituous compounds. As it may be made very capacious, it is able to receive a large quantity of liquid at once, but it passes through very slowly, and it is often necessary to wait for a long time before the liquid passes through clear, on which account these filters ought never to be used, unless when others are not fit for the purpose.

When syrups are to be filtered, instead of giving the flannel the form of a bag, the cloth is merely fixed upon a square frame, to which it is attached, at its four corners, by means of pegs. The boiling syrup is poured upon the middle of it, which almost always bags a little, and often, at the end of a few minutes, the liquor passes through very clear.

The filter thus disposed, may also be employed for filtering any other liquids, especially such as are of a watery nature, and which do not contain potash or soda in solution, for, were they never so slightly alkaline, the filter would be soon destroyed, and the filtered liquid rendered impure.

*Cotton Filters, or Tow.*

Carded cotton is reserved for filtering such fluids as are considered precious, whether on account of the difficulty of procuring them, or of the small quantity with which one is provided.

In order to form this filter, carded cotton or tow is introduced into the throat of a glass funnel, and stuffed in with a cane glass, so that it forms a kind of slightly compressed cork; the fluid which is to be filtered is then poured into the funnel. The filtration takes place drop by drop, and after the first drops have been separated and poured back again, those which follow are always clear. The essential oils may very conveniently be filtered by this means without danger of waste.

*Filtration through Glass.*

The acids, especially those that are in a concentrated state, can only be filtered through pounded glass; but this substance must not be used till it has been washed several times; at first, with a large quantity of water, and afterwards with an acid, in order to deprive it of the earthy or other foreign particles that might be dissolved by the acids which are to be filtered.

These filters are formed in a funnel. The great art that is required, in order that they may produce this effect, is, first, to fix some fragments of glass in the throat, afterwards to add other smaller fragments, and thus to continue always diminishing the size of the fragments, till a thickness of three or four inches has been formed; the upper layer of which ought to be glass reduced to fine powder.

This kind of filter lets the liquid pass through with sufficient facility, so that in less than an hour it is possible to filtrate several pounds of acid in a glass funnel of a moderate size.

## *Clarification.*

The clarification of liquids, simple as it may appear to be, nevertheless merits particular attention, especially when we consider the advantages which are obtained from it in the chemical and pharmaceutical arts.

### *Clarification by Rest.*

Clarification by rest is sometimes subject to several inconveniences, the chief of which are, that it requires a considerable length of time, and that during this interval the formation of new products often takes place.

A very striking example of what happens in this case, is the spontaneous clarification of the juices of plants or fruits. These juices, when fresh expressed, are always turbid: they nevertheless become clear by imperceptible degrees, but then their nature is no longer altogether the same.

### *Clarification by Egg, or gelatinous Substances.*

The effect of the albuminous and gelatinous matter is principally remarkable in the vinous liquids. It is on this account that they are employed when it is required to fine wines, and other fermented liquors; that is to say, when we wish to give them that high degree of limpidity which they can rarely acquire and preserve by mere repose. In this case, nothing more is required than to dissolve eggs, isinglass, hartshorn shavings, or any similar substance, in a small quantity of the liquid, and to mix this solution, cold, with the remainder. A short time after a kind of net-work is observed throughout the whole mixture, which, soon contracting together, collects all the foreign substances from the fermented liquor, and carries them with it to the bottom of the vat.

In other instances, it is necessary to heat the liquids with which the eggs are mixed, and it is only at the moment of ebullition that the clarification takes place: most of the foreign made syrups are clarified by this process, and no other has yet been discovered that produces a better effect.

It is also observed, that egg alone is not always sufficient to clarify liquids, even though they are raised to a degree of temperature sufficient to make them boil, but that it is necessary to assist its operation by means of an acid, or a salt with a redundance of acid. In proof of this, may be adduced what takes place in the clarification of whey; for it is only when there is added to this fluid at the moment when it begins to boil, some cream of tartar or vinegar, that the egg with which it had previously been mixed, coagulates, and carries with it the cheesy matter, which impaired the transparency of the whey.

It is absolutely necessary to separate the magma which forms in liquors that are clarified with egg, especially when in order to concentrate those liquids, it is necessary to evaporate them by the aids of ebullition. Without this precaution this magma would dissolve, and these liquors would become more turbid than they were previous to the clarification. It proceeds from a similar cause that broth, from which the scum has not been taken off, always retains a disagreeable appearance and will not keep.

Though the employment of albuminous matter for clarifying the juices of certain vegetables be of utility, it is however not without its inconveniences. Amongst others, one that has been remarked is, that it changes the nature of these fluids in such a manner as partly to destroy their medicinal properties. It often happens to certain pharmaceutical preparations, such as decoctions of medicines, that, when in order to clarify them, recourse has been had to white of egg and heat, they are almost without effect, unless we take care to double the proportions of the ingredients that ought to enter into their composition. Dr. Lewis has even remarked, that this operation deprived the syrup of white poppies of all its powers.

### *Clarification by Cream.*

New cream is employed with advantage for clarifying spirituous liquors, one or two spoonsful to the pint are sufficient to produce this effect in the space of

a few hours in the cold. But as in this clarification, some cheesy matters always remain suspended in this fluid, by reason of their great tenuity, it is necessary to separate them, at last, by filtration through a flannel bag, or through paper.

### *Clarification by Heat.*

There are some fluids which, in order to become clear, require to be subjected to a degree of heat nearly approaching that of boiling water. These are principally such as are rendered opaque merely by substance, the solubility of which cannot become complete unless it be facilitated by raising the temperature of their solvent above its natural state. Many saline solutions stand in this predicament, and whoever occupies himself ever so little with chemistry will frequently meet with such.

Most of the fresh expressed juices of vegetables may also be partially clarified by the operation of heat. Thus it is customary amongst foreign apothecaries to have recourse to this means with those juices which, on account of their thickness and viscosity, are not susceptible of being filtered.

Frequently a slight degree of heat applied to the expressed and filtered juices of certain vegetables is sufficient suddenly to destroy their transparency; in this case a flaky whitish substance floats in the liquid, and collects at the bottom of the vessel. This is the substance which Rouelle, the younger, considered as the vegeto-animal matter of corn, but which Parmentier demonstrated, in 1772, to be a substance analogous to the white of an egg.

## *Granulation of Metals.*

The malleability of metals renders it impracticable to reduce them to smaller particles by the mortar or similar means; chemists are therefore obliged to adopt other methods.

Filing is frequently adopted, but in the case of iron the filings rust very quickly, and spelter clogs the files so that they cease to act: hence the shavings of these metals obtained in turning them in a lathe are usually obtained from the manufactories.

Gold, silver, and copper, are granulated by melting them, and pouring them in a fine stream from a height of several feet into a vessel of water. Lead is also reduced in this manner into very small thin fritters, by holding a small iron ladle, having one or more pin holes in its bottom, three or four feet above a pail of water, and pouring the melted lead into the ladle.

Both lead and tin are granulated by pouring them, when melted, into a wooden box rubbed on the inside with chalk, then quickly covering the box, and shaking it briskly, the concussion of the metal against the sides of the box at the moment of fixing, reduces it to a fine powder, from which the chalk is afterwards washed off.

The perforated ladle and granulating box are consequently necessary instruments in a metallurgic laboratory, as also a pair of rollers, a wire-drawing machine, anvils and hammers of various sizes.

## HEATING APPARATUS.

The greatest part of this apparatus is so well known, that little need be said of it.

For ordinary purposes copper caldrons and skillets are used; but those of bronze or bell-metal are to be preferred, and for some particular purposes, it is necessary to have not only tinned copper, but also pewter vessels of this kind, as well as cast-iron kettles of various sizes, and iron ladles.

The best earthenware vessels for this purpose are the brown Nottingham ware, or those made of stone-ware. There are sometimes to be met with in the eastern parts of London, Dutch stone-ware jugs, the originals from which the patent mustard-pots have been copied, but much coarser in their appearance: these Dutch jugs bear the fire so well that they may be used for years to boil liquids. When elegance is studied, the Wedgwood-ware may be used.

The glass vessels used for this purpose, are glass capsules, which are generally supplied by cutting out the bottom of matrasses, boltheads, bodies, and retorts which have been used, or are accidentally broken.

Uncut bodies are, of course, used for merely heating large quantities of liquids in glass: if they are to be steamed away, the body is cut, to present a larger surface to the air.

Boltheads of platinum have been recently introduced for boiling certain metals in oil of vitriol, in order to dissolve them.

For digestions in glass, the matrass, or bolthead is used, and to prevent the loss of the volatile matter as much as possible, the neck of the matrass is left long, and is either closed by a bladder pierced by a pin which is left in it, or, as advised by Glauber, by a stopper formed of pewter, for which a glass stopper loaded with a weight may be substituted, or, according to the same excellent practical chemist, by luting on it a bent glass pipe, in which a little quicksilver is placed to serve as a moveable stopper, an apparatus which has been recently re-invented under the Gallic name of a tube of safety, or in plain English, a safety-pipe. Sometimes two matrasses are joined mouth to mouth, and luted together, the vapour that condenses in the upper vessel drips into the lower, and as it thus circulates, the apparatus is called a circulatory, and the operation itself is called circulation.

As it is difficult to get out any residuum from a matrass or even a bolthead, Dr. Lewis used a receiver, and luted to the mouth of it a narrow mouth adopter, which served as a neck.

Matrasses are sometimes made with the bulb oval instead of being spherical; these oval matrasses have generally a very long and slender neck, and are called philosophical eggs for digestions.

### *Apparatus for melting and calcining Bodies.*

When solid substances are to be exposed to intense heats to fuse them, or to favour their mutual chemical action, the ves-

sels, generally employed, at least for experimental purposes, are called crucibles.

The Hessian crucibles, which are manufactured only in Great and Little Almerode, and from hence exported all over the world, will support an intense heat for many hours, without softening or melting; but they are disposed to crack when suddenly heated or cooled. This inconvenience may be, on many occasions, avoided by using a double crucible, and filling up the interstices with sand, or by covering the crucible with a lute of clay and sand, by which mean the heat is transmitted more gradually and equally. These, which give a clear sound when struck, and are of uniform thickness, and have a reddish brown colour without black spots, are reckoned the best. The Saxon crucibles, particularly those of Waldenburg, are also highly esteemed, but not exported.

The Stourbridge clay skittle-pots are not baked, but merely dried; they have a very clumsy appearance, but bear a very intense heat.

Wedgwood's crucibles, made of porcelain clay, are very excellent for all experimental purposes in the small way. They are very smooth within, and stand a very strong heat. They should be covered with some coarse clay before they are exposed to the action of a very intense heat.

The black crucibles, formed of clay and blacklead, were formerly imported from Ipser in Germany, as the Dutch bought up all our blacklead; but are now made in England. Dr. Leigh says, several clays wrought together with powdered blacklead and horse-dung, make good crucibles; so that he seems to have been the inventor of them. The Sheffield crucibles of this kind are made of clay and powdered coke.

These crucibles are very durable, resist sudden changes of temperature, and may be repeatedly used; but they are destroyed when alkaline or saline substances are melted in them, and suffer a partial combustion when exposed red hot to a current of air; they answer best for melting metals. On account of these blacklead pots bearing the fire so well, and their being easily cut by a saw, or bored with a gimlet, Dr. Lewis used them for making portable furnaces.

Blacklead pots are in sizes, the largest being marked one hundred, which are about thirteen inches and a half deep on the inside, and ten inches and a half at the mouth. The next sizes are marked ninety, eighty, seventy, &c. without any intermediate numbers. They are generally about half an inch narrower one than another, though not with any exact regularity. Number sixty is about twelve inches deep, somewhat less than eight inches wide at the mouth, and six inches and a half at the middle of the height. These pots will generally fit into the second size above it, by means of sawing off some of the thick part of the bottom, and rasping off the edges; as eighty into one hundred, seventy into ninety, or sixty into eighty: the interval may be filled up with slaked lime mixed up with as much water as will render it sufficiently fluid to be poured in between them.

Macquer extols the Dutch pots in which their butter is exported, as the best crucibles known in Paris; they may perhaps be made of the same ware as has been already mentioned.

Iron crucibles are made, but seldom used; they are intended for melting the alkalies, either by themselves or with earthy substances.

Platinum crucibles and capsules, on account of the nearly absolute infusibility of the metal by the heat of chemical furnaces, and its unalterability by most agents, are of the greatest service in many cases. They should always be put into a common crucible to defend them from the direct action of the coals, the clinkers of which affix themselves to the sides and bottom with so much obstinacy that they cannot be detached without risk of injury to the vessel. But platinum is acted upon by nitrate of potash in fusion, and also by alkalies; and hence these crucibles cannot be used for the fusion of substances containing them.

Crucibles of perfect pure silver are particularly useful in chemical operations, for the fusion of earthy bodies with alkalies for which platinum vessels cannot be employed; but the utmost degree of heat they can bear is a moderate redness; and the metal acquires a crystalline texture by cooling, and is

extremely breakable, so that they must be frequently re-cast; for which purpose, the chemist ought to have a mould.

Calcining dishes are made of ordinary crucible ware, and are sold in the warehouses; but there are two other vessels of this kind which are always made by the metallurgic chemist himself, namely, the scorifying or clay test, and the bone-ash cupel or test, for which purpose he must have moulds of wood or brass.

These moulds are merely rings of brass or box wood, strengthened by an iron hoop, and are narrower at bottom than at top. The materials of which the cupels and tests are made being rolled by the hand into a ball, are put into the mould, and pressed down by a kind of brass-headed pestle, which fits accurately into the wider extremity of the mould, and would enter about one-third of the depth of the ring. The lower surface of this pestle is flat, with a projection in the centre, being a segment of a sphere, and thus forming a similar cavity in the upper part of the vessel.

The mould for clay tests is about three quarters of an inch deep, two inches wide at top, and an inch wide at bottom; the spherical projection at the head of the pestle, is an inch and a half wide, and rises three-eighths of an inch; the pestle enters a quarter of an inch into the ring. Fine washed Stourbridge clay, or any other equally refractory clay, mixed with the powder of the same clay, previously violently heated, and which is generally obtained from the upper part of crucibles that have been used, is put into the ring or mould, which has been slightly greased, and the pestle struck with a heavy mallet to render the test very solid. A circular piece of wood or card of a proper size, is then used to push out the test, at the wider end, which is then dried for use.

The cupel mould is about the same depth, an inch wide at top, and three quarters of an inch at bottom: the spherical projection on the head of the pestle is half an inch across, and rises a quarter of an inch: the pestle enters a quarter of an inch into the ring. The bone ash being sifted, but not with too fine a sieve, and moistened with water, is first pressed into the mould by the pestle in the same manner, and then dried for use.

Ash tests are made in a coarser manner by merely pressing into an iron ring, moistened bone ash, or wood ash, from which the salt has been extracted by elixiviation, and scooping a cavity in the upper surface; these tests are left in the ring.

## SUBLIMING APPARATUS.

When only those volatile substances that are solid are collected by the chemist, the operation is called sublimation.

The name bolthead is given to a spherical glass vessel, flattened a little at the bottom, and provided with a short thick neck, in which respect it differs from a matrass, the neck of which is long and slender.

In order to sublime any substance, a part of the globe of the bolthead is sunk into a shallow sand-pot, as deep as the matter which is to be volatilized as the heat rises. In this manner it is that corrosive sublimate, calomel, camphor, and other similar products, are formed for the purposes of commerce; the neck of the vessel is loosely stopped with a little tow, but the entire stoppage of the neck, as it would endanger explosion, is guarded against by occasionally thrusting a wire down the neck.

The heat is most commonly applied through the medium of a sand-bath, and the degree of heat, and the depth to which the vessel is buried in it, are regulated by the nature of the product; but very often the bottom of the bolt-head is coated with clay, and thus exposed to the naked fire, by being hung in a pot-furnace in place of the sand-kettle.

The cake of sublimate can only be got out of the bolthead by cutting off first the neck, then the bottom, and afterwards carefully breaking away the glass from the cake of sublimate.

To avoid this continual breaking of the glass in the repeated sublimation of the same substance, chemists use a long oval bolthead, with the neck placed on the side. This philosophical subliming egg being charged and placed on one of its ends, both of which are made thin for the purpose, the sublimate rises and is condensed in the other end of the longest diameter; the egg is then turned and the sublimate driven by the heat to the other end, and this repeated as often as the operator pleases.

Geber, about 800, proposed to make the bolthead in two pieces, by dividing the globe in the middle; but his advice has not been followed. Sublimation, however, is sometimes performed in two crucibles placed mouth to mouth, and closely luted; the sublimate being collected in the upper inverted crucible, whose bottom is guarded from the radiant heat of the fire by being placed out of the furnace. This may be looked upon as an adoption of Geber's suggestion.

Sublimation is also sometimes performed in a common earthen pipkin, on the mouth of which a paper cornet or cap is tied.

When chemists formerly wanted to have the sublimed substance in a powdery form, or flowers as they are called, they used a series of earthen or glass blind heads, open at top, the first placed on a cut body, and the other on one another; the last, or topmost being covered with a close glass blind head: but Homberg, in 1700, recommended driving over the volatile matter from a low short-necked retort into a very large glass receiver, as some chemists do at present, half-filling the receiver with water.

## COMMON DISTILLING APPARATUS.

This is of a more complex nature than any of the preceding apparatus, especially when aeriform products are to be collected, but for the present, only the common apparatus is considered.

The common copper still has been already described in treating of furnaces, in page 71, which serves for distilling the essential oils of plants, and the spirit of fermented vegetable juices and decoctions. An immense variety of these stills have been contrived for the latter, as will be shown hereafter, as they are solely destined for the manufacture of that single article.

## *Retorts.*

Retorts are the most employed of any kind of distilling vessels in the practice of modern chemistry, having in England almost superseded the use of all others. Formerly bodies, or matrasses with glass heads, were chosen for many operations, but large retorts, with proportionate receivers, are now preferred, except in particular cases.

The common form of retorts is not faulty, provided two kinds of them be had; the one short and thick, with short wide necks, resembling a body bent in the middle; and the other taller, with long, narrow necks, resembling a matrass with its neck bent down. The particular use of each of these kinds will be pointed out, in treating of the several operations to which they are intended to be subservient.

But it will be found very advantageous to have a stock of both sorts ready for all occasions; and to be prepared to render the necks shorter, and enlarge their orifices, according to the designed use.

It is usual to have this done at the glass-house before the retorts are sent from thence; but every good operator should perform it himself, in the manner suitable to the use the retort is to be applied to; for, on the adapting properly the size and form of the retort to the nature of the operation, the success, in many cases, depends in a greater degree than can be imagined by those who have not occasion to make accurate experiments of this kind.

For dephlegmating oil of vitriol, distilling ether, and many other such occasions, the retorts may be made of the substance of which the pots, &c. commonly called stone-ware, are formed. These stone retorts being much stronger in their texture, and not near so liable to be cracked with heat, will endure much longer than glass, and are much less dangerous in placing into the furnace, or taking out, if there be occasion, when containing acid spirits or other corrosive fluids. They may be obtained at the stone manufactories, at an expense but little exceeding that of glass; and they afford by their durability, a great saving compared to glass, where much business is done.

For ordinary purposes, retorts of green glass are used, either placed in baths, or coated and used in a naked fire; but for some purposes flint glass retorts are obliged to be used.

The sizes of glass retorts are prodigiously varied, more so than that of any other vessels: large green glass retorts are used that hold several gallons; while, for experiments, others are blown that really hold only a cubic inch of any liquid. It must be observed, that the denomination of a green glass retort, and its real content, are widely different; as the manufacturers use, it would appear, the St. Denis pint, from whence the manufactory was probably introduced, as their initial measure, which is equal to four English wine pints, and only reckon half its real content.

Some glass retorts have, in their arch, or helm as it is called, an opening to admit the addition of fresh matter during the operation; these are called stoppered retorts, or tubulated.

Retorts are also made of crucible ware, when it is necessary to expose the substance to be distilled to a very intense fire.

These retorts are so porous that they allow both air and water to pass through them when intensely heated; and, therefore, they must be coated. The English retorts of this kind are of the ordinary shape, but the Waldenburg, or German retorts, so highly praised, even by that ancient author, Basil Valentine, and still esteemed by the German chemists, resemble a bolt-head, with its neck so slightly bent in the middle that the retort is obliged to be set sloping in the furnace, to allow the liquid condensed in the neck to run into the receiver.

Earthen retorts are also sometimes made with an opening in their arch, or, as it is called by the manufacturers, stoppered.

Boerhaave, in his reverberatory furnace, used cylindrical retorts laid on their side, as already described, when that furnace was mentioned in page 85.

This cylindrical form of the retort has been recently much used for distilling wood, coals, bones, and other vegetable, animal, or bituminous substances. The cylinder being made of cast iron, open at one, or more commonly both ends, but stopped, while in use, with a flat plate of the same metal. That in the front of the furnace has a short neck, to which the pipe, conducting the vapours that rise from the substance, is connected; the hind plate, when there is one, takes off for the purpose of charging and emptying the retort.

In the distillation of any of these substances, the manufacturer should remember, that if the retort be allowed to cool every day, it will be soon destroyed by the action of the air; but if it be constantly kept at work; by discharging and recharging it without cooling, the vessels will wear for several years.

When it is necessary to cool the residuum gradually, as in distilling wood for charcoal, intended as an ingredient in making gunpowder, the cast iron cylinder is, in fact, only the coating of the real retort, which is made of sheet iron, and slips into the other, so that when the distillation is finished, it is drawn out, and a fresh retort, ready charged, is put in its place.

### *Alembics, or Bodies and Heads.*

Of all the vessels destined to this use the alembic is the most ancient. It differs from the retort in being generally composed of two pieces, the cucurbit, or body, into which the materials to be distilled are introduced, and the capital, or head, in which the vapours are condensed, and which fits closely on the top of the body, which is cut so as just to rise above the channel of the head. The capital, or head, has its external circumference, or base, depressed lower than its neck; so that the vapours which rise, and are condensed against its sides, by the contact of the surrounding air, runs down into the circular channel formed by its depressed part, from whence they are

conveyed by the beak, or nose, on the side of the head or capital, into the receiving apparatus.

The capital is sometimes stoppered, or pierced, that is to say, it has a small opening at the top, furnished with a ground stopper. This contrivance is convenient for introducing, from time to time, a fresh supply of materials intended to be distilled, without deranging the apparatus. The capital, or head, is sometimes made air tight to the body by grinding, or even made of one piece with it; but this method is expensive, and little, if at all, superior to closing the joint by lute.

Some authors have directed the neck of the head to be placed within the mouth of the body; but this would require them to be always ground together; when the neck is blown of a proper roundness, it fits the outside of the body so as to require scarcely any lute.

The alembic has this advantage over the common retort, that the residues of distillation may be easily cleared out of the body, which is not the case with the retort. It is likewise capable, when skilfully managed, of distilling a much larger quantity of liquid in a given time, than a retort of equal capacity. Besides this, the alembic may be used for causing the vapour of bodies to act upon substances in a more convenient manner than can be done by means of the retort and receiver.

Glass bodies are usually made from one pint to two gallons capacity; and are occasionally pierced, and even stoppered on the side, at about half their height. They are sometimes made of earthenware, or pewter, and the head only of glass; or of iron, with a stoneware head. A silver body, with a glass head, is necessary for the preparation of the pure fixed alkalies, and with a silver head for preparing fluoric acid.

Platinum boltheads, with heads of the same metal, are used in the concentration of oil of vitriol.

These alembics are very expensive in the first instance; that of Mr. Parke's cost three hundred pounds; but the frequent accidents which happen, in concentrating the acid in glass, counterbalance the expense.

It must be observed, that at the temperature in which this concentration is effected, lead unites with platinum, and they melt together. So that it has happened, that some small grains of lead having fallen into a platinum alembic, have made holes through it: the utmost care should, therefore, be taken, to avoid this mischance. But should it happen, the damage may be repaired by soldering in small plates of platinum, by means of pure gold.

Glass matrasses, with glass heads, are also used as alembics; these heads are generally of white glass and stoppered.

A series of heads, the lower being all open at the top, are sometimes placed one on another, by which the operator endeavours to procure the distilled liquor of different strengths, according to the height the vapours are made to rise; this apparatus is called a *hydra*, from its numerous heads.

Other chemists have endeavoured to send over only the most volatile parts into the receiver, and to let the other return into the body; for this purpose, some, as the old chemists, used a long winding neck to the body, on which the head was fitted, and this vessel they called, in the mysterious cant in which the chemists of all ages, even to the present day, take delight, a *serpent:* others

in later times, have prolonged the top of a blind head to a great length, and brought it down again, in a similar winding course, to a level with the other part of the head, as Barchusen, as may be seen in the view given of his laboratory, in plate 11.

All these glass vessels which are exposed to heat, require some management and care to prevent them from breaking. If any solid substance be put into a retort, or body, which adheres to the bottom of it, when over a lamp, it is almost sure to break.

If a glass retort be laid down, while hot, upon a substance capable of conducting away the heat from it rather quickly, there is almost a certainty that it will break; but it may be laid down upon a piece of woollen cloth, a roundel of straw, bound with list, or on dry glass, or even very dry sand, with safety.

### *Receiving Vessels.*

Receivers, properly so called, are large glass globes, which should be also always had with short and wide necks, so that the hand may be introduced with ease to extract any solid matter, or to clean them. They should be much larger, for most purposes, than what are generally used. A greater quantity of condensing surface renders the operation both more profitable and safe: it prevents the forcing of the lute and the escape of the vapour, as well as the hazard of bursting the vessels, on raising the fire too high, if the luted juncture should hold good against the force of the expanded vapour; or the necks of the retort, or adapter, and receiver, should fit so exactly as to admit no passage for it.

As the mouths of receivers, properly so called, whatever may be their size, should always be of nearly the same width, and the retorts, and beaks of the heads, to which they are to be adapted, are of many various diameters, the chemist must have a sufficient number of adapters. These adapters are pipes of white glass, about two feet long, one end of which is fitted to embrace the neck of the retort, and the other to fit into the neck of the receivers.

Besides their use in adapting the beak of the retort, or of the alembic, to the neck of the receiver, adapters have a farther use in removing the receiver farther from the furnace, and thus keeping it cooler.

When the vapours require a considerable degree of heat to raise them, and come over very hot, if the drops fall on a cold part of the receiver, they are apt to crack it; in this case, if the neck of the retort is short, another kind of adapter must be used to lengthen it, so as to reach the very centre of the receiver, that the hot drops may fall into the liquid that has previously come over, or into some liquid placed there for that purpose: these adapters are sometimes of stoneware, or even of iron.

Receivers are generally made of green glass, but when white glass adapters are used, stoneware jugs of sufficient size may be used for receivers, as the progress of the distillation may

be judged, by the temperature of the adapter, and the appearance of the vapours in it.

As the substances disengaged by heat are sometimes not condensible, even by putting water or other liquids into the receiver, a passage must be left for them. Some, before luting, put a piece of stick between the joint of the retort, or adapter, and the receiver, and take it out occasionally; but the more ordinary method is for the chemist himself to make an opening in the globular part of the receiver, taking care in placing it that this hole is uppermost. For common purposes the hole is stopped with a bit of stick, and hindered from falling in by a collar, or with a piece of soft wax. The flint-glass receivers, used by lecturers and amateurs, have a hole surrounded by a collar, to which is ground a glass stopper, by the manufacturer.

If it is supposed that the vapour is condensible, although with difficulty, a long and wide barometer cane is luted into this hole, so that the atmosphere acts like a stopper on the vapour: steam and air, not easily mixing together, but remaining perfectly distinct in pipes; and even for a long time in the open air, as may be seen daily in wash-houses and brew-houses.

For the purpose of taking away a part of the liquid product, during the progress of the operation, without the necessity of unluting the joints, some receivers have a short pipe, called a quill, on their sides; so that when they are fitted at a proper angle to the retort, the quill may be in the most depending part of the receiver, hence the liquid that comes over, flows thus into a bottle placed to receive it, and which may be removed occasionally, and the bottle have its place supplied by another.

Instead of allowing the uncondensible produce to pass out, an attempt is sometimes made to retain it in the vessels for some time, to allow it to deposite all the condensible parts, by increasing the size of the receiving apparatus beyond that of a single receiver; so that the additional pressure of the newly-produced aeriform fluid above that of the atmosphere being rendered less in proportion to the capacity of the vessel, may not occasion an explosion of the vessel. For this purpose, receivers are made with a second neck opposite to the ordinary opening; this neck is conical, to fit into the mouth of the next receiver, and thus a long file of these vessels is formed.

Various combinations of the above-mentioned kinds of receivers are used to suit the various purposes of the chemists.

Instead of these wide short-necked receivers, glass alembics have very commonly a matrass luted to the beak of the head to serve as a receiver.

### *Feeding Apparatus.*

There is often occasion to add to the matter in the retort, or other distillatory vessel, some substance to produce certain effects; without admitting air or letting the vapours escape through the hole by which they are introduced, and several apparatus have been devised for this purpose.

Fig. 70.

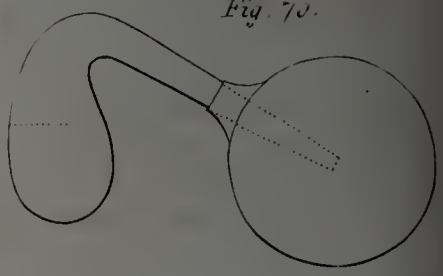
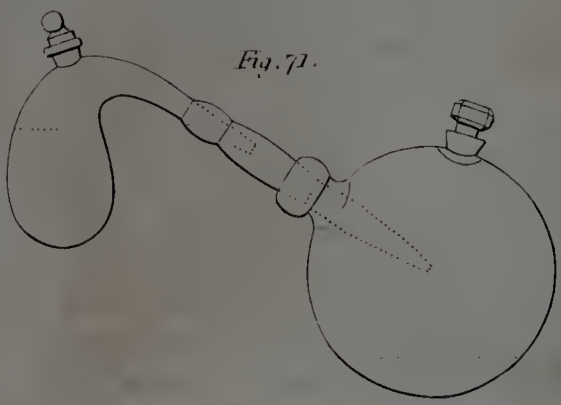


Fig. 71.



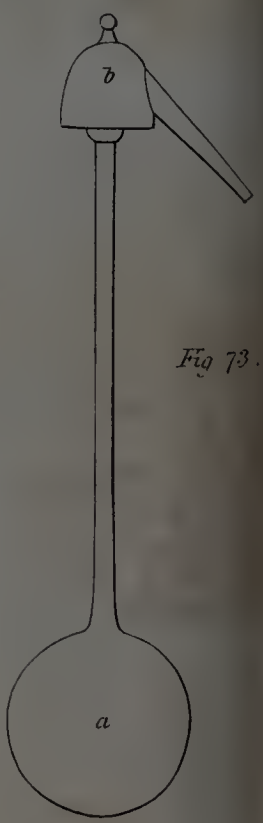
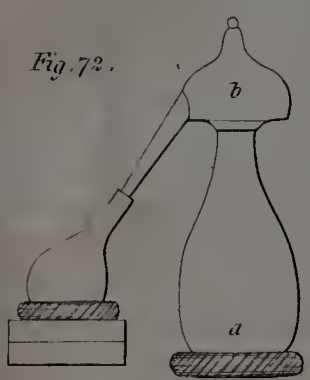



Fig. 73.

Fig. 72.



The most simple is the glass funnel and rod; the funnel has a very short pipe just sufficient to fix it in the hole in the arch of the retort, or the top of the head, and is stopped by a solid glass cane, which is ground to fit the throat; the liquid, for substances of that consistence can alone be used in this manner, is poured into the funnel, and by loosening the cane, it is allowed to drop or enter the vessel in a gentle stream, as may be judged proper, or its entrance may be instantly stopped.

Another apparatus of this kind, not more efficacious and liable to accidents, but certainly more tricksome, and therefore better adapted for a popular lecturer, is the hydrostatic funnel, in which the liquid itself serves as the stopper. A very long glass cane is luted into the hole in the arch of the retort, rising up perpendicularly, then bent so as to reach down within an inch or two of the hole, and again bent upwards to reach three or four inches above the first bend; this upper extremity of the cane is either widened or has a very small funnel placed in it. The liquid which is to be added to the substance in the retort, is poured into the cane until it stands in the second uprising part on a level with the bend, between the first upright uprising part and that which descends. This portion of liquid serves as a stopper: whatever is to be added is then poured at the proper time, into the upper extremity of the glass cane. Should, however, at any time, the vapour in the vessel be suddenly condensed by absorption or otherwise, the whole of the liquid in the cane is suddenly jerked, by the pressure of the atmosphere, into the bowl of the retort, and breaks it. On the contrary, if the vapours or gases in the distilling apparatus increase, the liquid is pushed up the cane, and is thrown out at the top.

To a still more complicated apparatus of this kind the name of Acid Holder is given, which is a flint glass bottle, open at both ends, furnished with a glass stopper at the upper end, and a short pipe with a glass cock at the lower end. Its use is to convey an acid, or any other liquid into a retort or apparatus, to which it has been previously adapted, without admitting the external air into the vessel, or suffering the gas within to escape out of the vessel.

This contrivance is very useful for preventing vapours or gas from escaping into the laboratory during the process; a circumstance of considerable importance when the gas or vapour has an unpleasant smell, or is of an unwholesome nature.

The cock being shut, the acid holder is filled with the liquid, and is then fixed into the opening of the retort, to which it is accurately adapted by grinding.

If it be found necessary to renew the liquid without disturbing the apparatus, this may be done as follows. The cock being shut, the stopper at the top of the acid holder is removed, and fresh liquid poured in through the mouth; this may be repeated as often as is necessary.

The size of the acid holder is usually from a quarter of a pint to a half; they are seldom used but in experiments to ascertain points of theory, or in giving lectures to the higher classes of society, when the vapours or gases have a disagreeable smell, or effect upon the lungs; as the admission of these elastic fluids into the lecture room might cause an audience of this kind to desert the lecturer.

The following figures represent some of the various articles of apparatus lately mentioned.

Fig. 70, a retort, with a receiver, not luted.

Fig. 71, a stoppered retort, with an adapter, and pierced receiver.

Fig. 72, a glass alembic, composed of a body, *a*, and its head, *b*, which is stoppered: to these distillatory vessels is attached a bolthead for a receiver.

Fig. 73, a glass alembic, composed of a matrass, *a*, to which is fitted a glass head, *b*.

Fig. 74, a pierced retort, fitted with a funnel and rod.
Fig. 75, a pierced retort, fitted with a hydrostatic funnel.
Fig. 76, a pierced retort, fitted with a stoppered acid holder.

## APPARATUS FOR PNEUMATIC DISTILLATION.

The next class of apparatus is destined not only for collecting the solid and liquid substances volatilized from bodies by heat, or obtainable from them by mixture, but also the aeriform substances, usually called gases or airs.

The method of collecting these elastic fluids or gases, although simple, is not however obvious at first. They differ so little from the atmospheric air in density, that they are not sufficiently ponderous to be detained in open vessels; besides, they all mix with one another in a very short time; and many of them act upon bladders in which they were at first collected. Their remarkable lightness, however, affords a method of confining them by means of denser liquids, for which purpose water and quicksilver are used.

The first requisite, therefore, is the water-trough, or hydro-pneumatic apparatus, as it is called by those who delight in grandiloquence; these troughs are made of various sizes.

Large troughs are made of wood, and lined with lead, about four feet long, three wide, and two deep; having a wooden shelf fixed at one end of the trough, about three inches under the surface, and reaching about one-third of its length. This shelf is perforated with holes, for the convenience of pouring the gases from one jar to another, by means of a very shallow and broad funnel of light wood stuck in the funnel.

Small water-troughs are, for the sake of lightness, usually made of thin iron plate, and japanned both within and without. They have two handles, by which, if not too large, they may be removed from one place to another, even when full of water, and a cock near the bottom to let out the water.

Fig. 77, represents the small japanned troughs usually sold in London, and being about eighteen inches long, nine broad, and fourteen deep. The shelf is of the same material, and about three inches and a half below the top. This shelf is moveable, as it runs in a groove, and has, near its outer edge, two or more holes, *a*, to which are soldered, underneath japanned funnels, to secure and convey the gases to the vessels in which they are to be collected. They have also two other holes, *b*, in the hinder part of the shelf, into which are occasionally placed bottle-holders, *c*, to support narrow mouth bottles, which would not otherwise stand firm.

When this trough is to be used, it is to be filled with water, so that it may rise about an inch over the shelf. Now if a bottle, *d*, or any other vessel, is plunged into the water with its mouth uppermost, it will fill with water, and, on being turned in the water, so as to have the mouth downwards, and slid upon the shelf, it will remain full of water, for the water is supported in it by

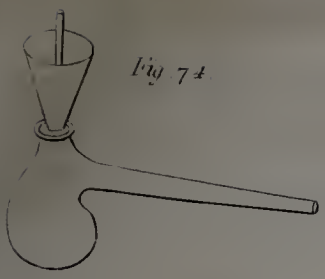


Fig 74

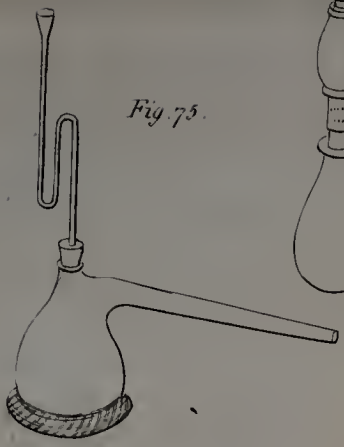


Fig.75.

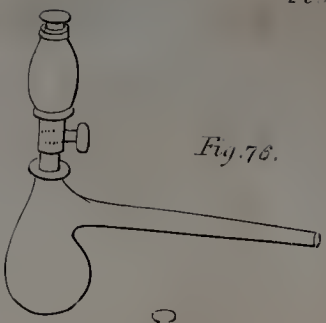
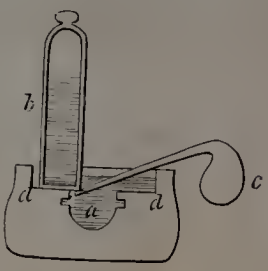


Fig.76.



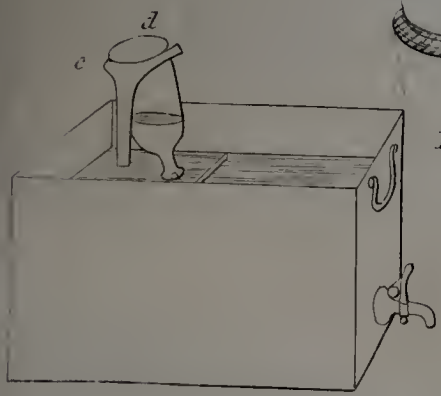




Fig.77.

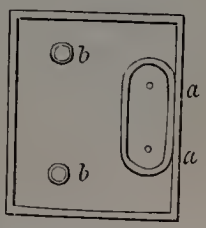
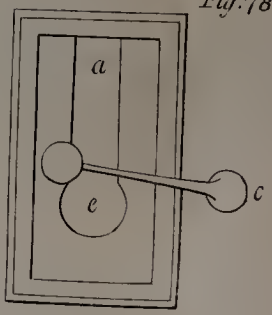



Fig.78.



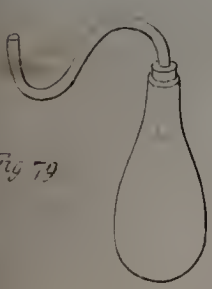



Fig 79

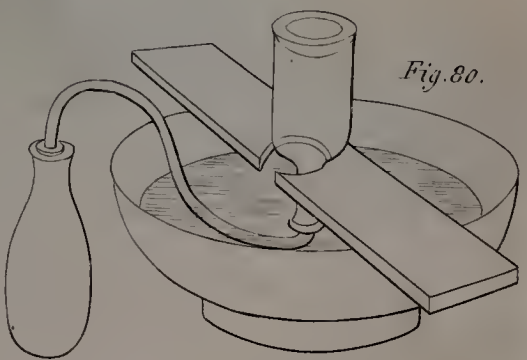


Fig.80.

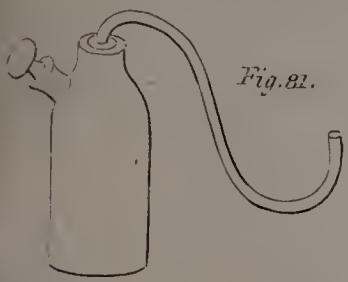


Fig.81.

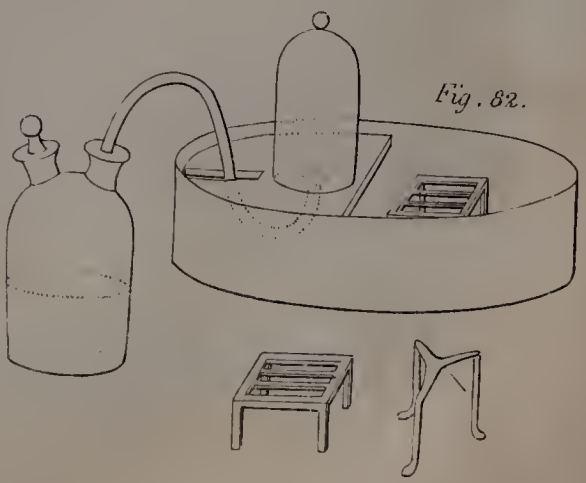


Fig . 82.

Fig.83.

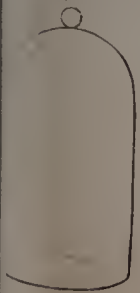
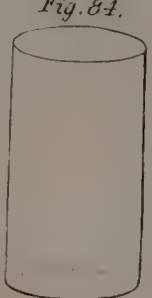


Fig.84.



the pressure of the atmosphere in the same manner as the quicksilver in the barometer.

If another empty bottle, as it is usually called, though really full of air, be put into the trough, mouth downwards, scarcely any water will enter, and if the bottle be brought under the edge of the shelf, and then slowly turned up, the air escapes in bubbles, and, if the operation is properly conducted, will rise through one of the funnels and holes, *a*, into the bottle standing on the shelf, and thus gradually expel the water and take its place.

It is in this manner that chemists transfer any kind of gas or air out of one vessel into another, by causing it to ascend by an inverted pouring, in which the lighter fluid is made to ascend from the lower vessel under the shelf, to the upper vessel standing on it, by the action of the weightier fluid.

Many gases are so quickly absorbed by water that it is necessary to receive them in vessels placed in a trough filled with quicksilver. These quicksilver troughs, or mercurial pneumatic apparatus, are made of marble, or cut out of a solid block of mahogany. On account of the weight and expense of this liquid metal the trough is made smaller, and the cavity for the immersion of the vessel is no larger than is necessary; the broad shallow part of the trough supplies the place of a shelf, on which the jars may stand, and there is put occasionally an actual shelf, at one end of the deep cavity.

Fig. 78, represents a quicksilver trough cut out of a solid block of stone or close wood. The deep space, *a*, admits the jar, *b*, to be immersed, and when full it is raised and placed, bottom upwards, upon one of the shallow banks. *C*, is a retort, from which gas being extricated, rises up in bubbles and displaces the quicksilver. *D*, are two grooves for a shelf, when required, which must be put in at the wider part, *e*. The best quicksilver troughs are made out of a much deeper block, and have a deep cylindrical hole at one end, in which a small cylindrical jar may be sunk, so that the surface of the quicksilver in the jar and the trough may be upon a level.

The glass jars used with this trough must be much smaller than those used for the water-trough; and they ought to be stout, as they are liable to be overturned, in consequence of their buoyancy, in so heavy a liquid as quicksilver, they must generally be supported by bottle-holders, fixed to the side of the trough.

When only the aeriform product is to be collected, small retorts, with long beaks, may be used to prepare and transmit it to the vessels in the trough, as represented in fig. 78, or small boltheads, with a bent hollow glass cone, passed through a cork, and luted, fig. 79, may be used: if this apparatus is too simple and cheap to please the chemist, gas-bottles, either plain, fig. 80, or stoppered, figs. 81, 82, may be purchased with bent tubes ground into them: it is generally necessary to cut off part of the tubes, with which they are usually too plentifully furnished, before they can be conveniently used.

To receive the gases, or airs, as they pass into the trough, the most simple apparatus are glass bottles. These may be filled one after another, and, being stopped with corks, or ground stoppers, while they are in an inverted position, with their mouths under water, may be placed, mouth downwards, in a large trough, or cistern of water, until they are wanted.

Bell-glasses, fig. 83, or cylindrical air-jars, fig. 84, are generally used when the gas is to be used immediately.

When all the products are to be collected, whether dense or gaseous, a more complicated apparatus is necessary; and a number of them have been contrived by different chemists, of which only those useful in practical chemistry will be noticed.

The apparatus of Mr. Pepys, and Burkett, however ingenious, are passed by on account of their glass valves; and that of Girard, because it does not admit of sufficient pressure being given.

### *Hassenfratz's Compound Distillatory Apparatus.*

The distillatory apparatus pointed out by M. Hassenfratz to M. Lavoisier, generally consists of a retort, *a*, a pierced receiver, *b*, and a series of bottles, *c*, connected with each other, and with the trough, by bent hollow glass canes, *d*: an adapter is also generally used.

The receiver, *b*, fig. 85, is designed to collect any condensible part of the product. In the three bottles water is placed to nearly one-half their height, and the canes passing from the one into the other, beyond the second bottle, *b*, dips into the water of the bottle into which it is inserted, as is represented in the plate.

The gaseous product is thus transmitted through the water, by which, as well as by the pressure which is necessarily exerted by the short column of water in each tube, its absorption is promoted; and if any portion is incapable of being absorbed by the water, it passes off by the bent cane at the end, and may be collected in a bottle or jar, inverted in a trough of water.

Each of the bottles, except the receiver, has a straight cane, *e*, *f*, *g*, which rises to the height of about ten, thirteen, and sixteen inches above its insertion into the bottle, and passes so far within it, as to dip into the water nearly half an inch. These canes are termed the safety-pipes, and the use of them is to guard against that reflux of fluid which might happen from a partial vacuum arising from condensation in any of the bottles.

It is evident that, in the course of operations with this apparatus, the liquor of the bottles must rise in these tubes in proportion to the pressure sustained by the gas or air contained in the bottle, and this pressure is determined by the height and gravity of the column of fluid contained in all the following bottles. Now, supposing that each bottle contains three inches of water, and that there is the same depth in the cistern of the connected apparatus above the orifice of the tube, *d*, and allowing the gravity of the fluids to be only equal to that of water, it follows that the air in the first bottle must sustain a pressure equal to twelve inches of water; the water must, therefore, rise twelve inches in the cane, *g*, connected with the first bottle, nine inches in the cane of the second, *f*, and six inches in *e*, that belongs to the last; wherefore these tubes must be made somewhat more than twelve, nine, six, and three inches long, respectively, as an allowance must be made for oscillatory motions, which often take place in the pipes.

It is sometimes necessary to introduce a similar tube into the receiver itself, and as the tube is not immersed in a liquid at its lower extremity, until some has collected in the progress of the distillation, its upper end must be shut at first with a little lute, so as to be opened according to necessity, or as soon as there is sufficient liquid in the receiver to secure its lower end.

At the commencement of the distillation, the joinings of the canes with the bottles being well secured, the whole is air-tight; and, by the gas produced, the atmospheric air contained in the upper part of the bottles is, in a great measure, expelled through the tubes. If, therefore, in any stage of the distil-

Fig. 85.

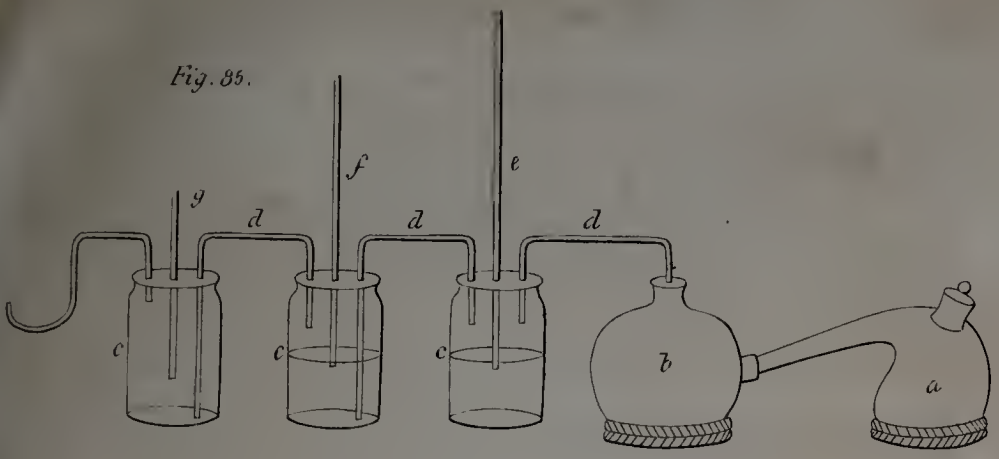



Fig. 86.

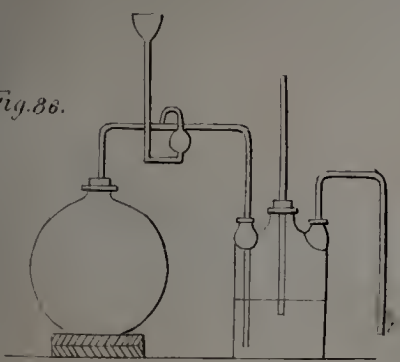


Fig. 87.

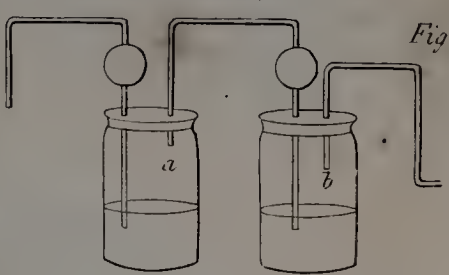



Fig. 88.

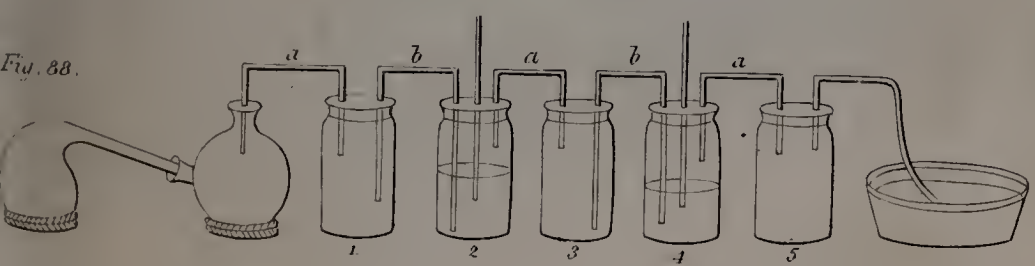
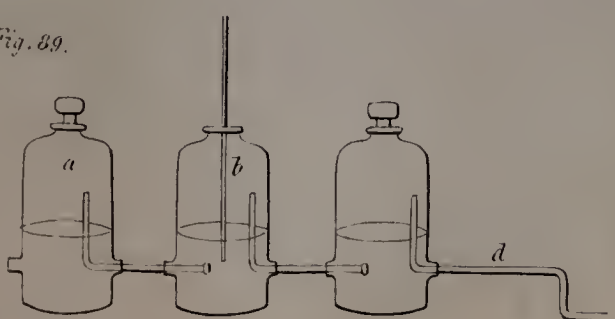



Fig. 89.



lation, the production of gas should diminish, then, on the quantity contained in the bottles being absorbed by the liquor, a partial vacuum will be formed; and at the end of the process, when the retort cools, this must always happen. The consequence of this will be, that the water in the trough being more pressed on by the atmospheric air without, than by the gas within, would pass backwards from one bottle to another, by rising through the tubes; and thus the whole of it would be mingled together in the receiver, which would often defeat the object of the distillation. The safety pipes effectually prevent this, as when any such partial vacuum happens, the atmospheric air is forced into each of them through the small quantity of fluid in which they are immersed, and, rising into the bottles, preserves the equilibrium.

One defect in this apparatus is, that the advantage of the immersion of the cane which passes from the receiver into the liquid in the first bottle is lost; for, as the receiver is almost always designed to collect the condensible product, and ought, therefore, to be without water, it can have no safety tube; and hence, if the tube issuing from it dip into the liquid in the second, whenever any condensation happened, from the gas ceasing to be produced, the liquor would pass backwards into it. The apparatus, therefore, is represented as it ought to be, with the bent tube from the receiver only reaching near the surface of the liquid in the bottle, *b*, while in the others it is immersed.

As the liquid, however, in this first bottle, is in the best situation for being impregnated with the gas, and, therefore, for forming the most concentrated product, it is of some importance to aid this as much as possible, and to obtain the advantage of the gas being forced to pass through it, by the tube passing into it being immersed.

### *Welter's Safety Pipe.*

The contrivance that has been used for this purpose by experimental chemists, is Welter's safety pipe, or bent tube, with an additional curvature, and a spherical ball, as intermediate between the globular receiver and the first bottle, and connecting them.

In this safety pipe, which is represented in fig. 86, is put a small quantity of water, so as to rise, when the pressure without and within is equal, about half way into the ball. If the elasticity is increased in the internal part of the apparatus during the distillation, by the production of gas, the water is pressed upwards to the funnel at the top; if there is a condensation, it is forced by the atmospheric pressure into the ball; but whenever it has passed the curvature beneath the ball, it is obvious, that a portion of air must rise through it, and will pass into the globe, or bottle to the tube of which this bent tube is adapted.

The safety-pipe, however, though it answers the purpose effectually, is inconvenient; from its form, it is very liable to be broken; and, what is its principal defect, we can employ no great pressure in the apparatus with it, without making it of such a length as to be unwieldy, and still more liable to be broken, since the bend must be as long as the cane in the first bottle, or even longer.

### *Murray's balled Pipes.*

The method employed by Dr. Murray, to obviate this inconvenience, is more simple.

It consists in having the usual bent glass canes constructed with a ball in that leg of it which is inserted in the bottle containing the liquid into which it is to dip, as represented in fig. 87. By properly proportioning the depth to which the tube is immersed in the liquid in *b*, to the size of the ball, it is obvious, that when from any condensation in *a*, the liquor in *b*, rises and fills the ball, the extremity of the tube will be no longer immersed; a portion of the gas will therefore rise in it through the water, and preserve the equilibrium, so that if the tube be not too deeply immersed, no part of the liquid in *b*, can ever pass into *a*.

The use of balled pipes of this kind, supersedes entirely the use of safety-pipes, through the whole apparatus; for, if the depth to which their lower ends are sunk in the liquid in the bottle be duly proportioned to the size of the ball, the reflux of the liquid will be totally prevented, while a pressure of any extent may be obtained by a pipe issuing from the last bottle, being sunk in the water, or quicksilver of the trough, to any desired depth.

This apparatus is certainly the best hitherto proposed, nor does it seem probable that any great improvement can be made in it.

### *Coxe's Apparatus.*

Dr. John Redman Coxe, Professor of Chemistry in Philadelphia, communicated to Dr. Thomas Thomson, an apparatus nearly of the same nature as the last, which was published in the Annals of Philosophy, for 1813, and is of easier execution than the apparatus of Dr. Murray, as it requires no other but the common barometer canes, although in other respects inferior.

To the pierced receiver of the usual distillatory apparatus is annexed a series of an unequal number of bottles, the first, third, and fifth of which are empty, the second and fourth half filled with water or any other appropriate liquid, as represented in fig. 88. Particular attention is to be paid to the arrangement of the glass canes; those from the receiver to the first bottle, the second bottle to the third; and the fourth to the fifth, *a*, have both their legs very short, so as to descend not more than half an inch below the opening in the retort, and the mouths of the bottles; on the contrary, those from the first bottle to the second, and the third to the fourth, *b*, have their legs sufficiently long to reach to the bottom of the bottles; and that from the fifth to the trough only descends a little below the mouth of the bottle.

Straight glass hollow canes, *c*, of different lengths, on the principles already pointed out, are inserted into the mouth of the bottles which have the water or other liquid put in them, and descend about half an inch below its surface.

Now if any condensation or absorption takes place, the liquid in the next succeeding filled bottle, or in the trough, will be drawn up the canes, and pass, at least in part, into the bottle left empty for that purpose; but it cannot go farther backward, because, as soon as the bottom of the safety pipes, *c*, are

left bare, the atmospheric air will enter by them, and thus prevent the liquid in the following bottles, or the trough, from being drawn over. And although the liquid in the second bottle may still continue to rise and pass into the first, by the pressure of the atmosphere through the safety-pipe, yet, as the cane connecting the receiver and the first bottle, merely enters the first bottle, and does not descend to any depth, the liquid cannot pass by it into the receiver. And the case is the same with the liquid in the trough.

When this absorption or condensation has taken place, and the production of vapour and gas continues, as soon as they are sufficient to support a column of liquid equal to the height of the legs of the longer canes, the water or other liquid which has come over into the bottles that had no water or other liquid placed in them at first, will be forced again into its former situation.

If a stoppered retort or other distillatory vessel is used, and the operator chances to observe the absorption or condensation, the atmospheric air may be readmitted into the apparatus still more readily by opening it.

There is no absolute occasion for any safety-pipes in this apparatus any more than in Murray's, provided the operator is careful that the last empty bottle shall be of sufficient capacity to hold the liquid that may, on occasion of any absorption, flow back into it, until the end of the pipe, which passes into the trough, be uncovered by the sinking of the liquid in the trough.

### *De Butt's Apparatus.*

A very convenient distillatory apparatus has been invented by Dr. De Butt, of Baltimore. It consists of two or more bottles, each of which have two openings made in them, opposite to one another, and near the bottom.

The first bottle, *a*, fig. 89, is connected with the distilling apparatus by means of a quilled receiver, or a hollow glass cane luted into the smaller neck of a double-necked receiver; one of the side holes is stopped. These are connected with the next bottle, *b*, by a tube straight without, but which has such a curvature within the bottle, *a*, as to rise above the water employed to condense the gas, the surface of which is represented by the dotted line. The succeeding bottles are connected in a similar manner. And the last bottle has a pipe, *d*, that passes into the trough.

It is obvious that the gas passes forward through the bent tube, and is transmitted through the water in the next bottle. The tubes may be fitted by grinding, but it is difficult to have this done with perfect closeness; they therefore may be inserted by corks waxed; and as these are not exposed directly to the gas, but are under the liquid, they will, in general, be little acted on. Safety pipes are adapted in a similar manner; and as it is inconvenient to detach the bottles, the liquor, when the distillation is completed, may be drawn off by a syphon inserted into the mouth of the bottles, or by an opening in front at the bottom, fitted accurately with a stopper or waxed cork.

The peculiar advantage of the apparatus is, that all the joinings, with the exception of the first, are under water, and the gas, therefore, cannot escape. Hence, in distillations, in which

the product is peculiarly offensive, as in that of chlorine, it affords the best security against any noxious effect.

### *Kerr's Gas Apparatus.*

Persons who are but little or not at all acquainted with chemistry, are often deterred from attempting even any experiments that may occur to them, from an idea of the expense of the requisite apparatus, and the supposed want of room.

The mechanic sees immediately the economy that attends trying the effects of a new engine by means of a working model; the architect exhibits, in like manner, the effect of his design by a model far better than by a draught upon paper; and yet with but little outlay of money. The experiments of the chemist may also be made in a miniature at a trifling expense. Beecher, that indefatigable artist in this line, was the first that practised this microscopic chemistry, as it is sometimes called in contempt. Cronstedt succeeded; then Engestrom, Bergmann, Gahn, Wollaston, Marcet, and Berzelius.

The glass tubes, lately described by Mr. Kerr, are to be considered as a continuation of the same scale of experimenting as with the blow-pipe.

Fig. 90, represents Mr. Kerr's tubes. The simple tubes, *a*, are hollow glass canes from six inches to a foot in length, and from a quarter to nearly half an inch wide, and of course, will allow of operating upon a quarter of an ounce to three quarters of liquid. They are closed at one end, *b*, and bent a little below the middle, so that the two branches may diverge from each other nearly at a right angle; the closed branch being somewhat shorter than the open one. The bend of the tube should be widened on the hollow side, and that more towards the short than the open branch, as represented in the figure. The bulging part, *c*, of the convex side, does not correspond with *d*, that of the hollow or concave side, but is beneath the short branch.

From this form being given to the glass, the gas that is evolved from a liquid by its action on a solid may be collected with ease in the closed branch, in the following manner:—The tube is to be held so that the open end be the highest, and then the liquid is to be poured in until it rises a little above the bend. On turning up the closed end of the tube, so that it may be as high as the open end, the liquid will still remain in the closed end, being supported therein by the pressure of the atmosphere. The solid body being then put in at the open end, will fall down to the bulge in the bend on the convex side, and if any gas is evolved from the mutual action of these bodies, or by the action of heat, it will pass through the liquid, and be collected in the closed end of the tube, unmixed with common air. The quantity of gas evolved may be easily ascertained by pasting a piece of paper to the tube, and afterwards weighing the quantity of water required to fill that part of the tube.

The same tubes, or rather those of a larger size, may be used for discovering the quantity of gas absorbed by any liquid.

In these experiments of absorption the open end must be corked, that the absorption may be limited to the gas or air contained in the tube itself. The quantity absorbed may be discovered by pasting a paper mark at the places the gas stands at, both before and after the experiment, and weighing the quantity of water, the tube will hold between the two marks.

If the experiment require a considerable time to be performed, the bend of the tube may be passed through a slit in the shelf of the trough, *e*.

Mr. Kerr has since contrived another sort of these tubes, in order that the gas that is evolved at any period of an experiment may be examined without giving any disturbance to the progress of the experiment, by mixing any liquid with the materials in the tube, or even mixing the gas that is disengaged with the air of the atmosphere.

These tubes differ, indeed, but little from those above described, except in so much that they are open at both ends, and are bent in three places. The first part of the tube, *f*, being that by which the materials of the experiment are to be introduced, and which is bent horizontally at the bottom; and after a little distance bent again upwards, as seen at *g*, the tube is then bent again downwards, and this descending branch is open, but stopped at pleasure by a cork or glass stopper, *h*, ground to fit it. If cork is used, it will in general require to be soaked in wax, and coated with that substance, in order that it may resist the action of acids.

The tube being closed, either with a stopper or cork, the liquid is poured into the first branch, *f*, until it has filled the whole of the second branch, *g*. The manner of doing this has been already described. The tube is placed so that its first bend, at the bottom of *f*, shall be its lowest point, and then the solid substance is dropped into the liquid. When the action commences, the gas that is disengaged will rise into the ascending part, *g*, of the second branch, and will displace the liquid, forcing it to rise up in the first branch. But some of the liquid will still remain in the descending part, *h*, of the second branch; and this ought to be run back and mixed with the main body of liquid, which is easily performed, by merely raising the stopper-end of the tube a little higher than the upper bend, between *g* and *h*. If the tubes are properly bent, so that the angle formed by the branches, *g* and *h*, be greater than the angle formed by the branches, *f* and *g*, there will be no fear of spilling any liquid from the open end of the tube, nor of introducing any atmospheric air to mix with the gas that is collected.

For the purpose of transferring the gas that is formed into another tube, the lower end, *h*, of the descending part of the second branch, must be brought under the surface of water or quicksilver in a trough; and the stopper or cork being then taken out, as much gas as may be desired may be transferred.

For the convenience of making several experiments at one time, Mr. Kerr uses the small trough, *e*, ten inches long, seven inches deep and wide, with a shelf having four slits, for the purpose of holding the same number of tubes. This shelf, *i*, is placed on one of the sides of the trough, and rests on a bracket. Within the trough itself, and in the side next the just-mentioned shelf, is placed another shelf, *k*, the length of the trough, that is to say, ten inches, about three inches and a half broad, and one inch or two below the surface of the water. This shelf has slits in it, which correspond to those of the shelf that hangs upon the edge of the trough. This construction of the trough was adopted that the liquid in the tube might be heated when necessary.

The first branch, *f*, is represented as having a globular enlargement, which is only necessary when this first branch would not otherwise be sufficiently large to hold the liquid forced out by the gas from the second branch, *g h*.

### *Ignited Adapters.*

Volatile substances, when exposed to heat in the ordinary distilling apparatus, rise in vapour, and thus escape from the farther action of the heat: it is, however, frequently desirable to cause them to undergo its full operation. For this purpose, several contrivances have been adopted.

The first and oldest method is that of using a slender adapter, between the distilling vessel and the receiver, and making a fire round it, so as to ignite it thoroughly, and then beginning the distillation, causing the vapours to pass through it in that state. In order to prolong the action of the heat on the vapours, the adapter is sometimes filled with a substance to delay its passage, and thus cause its complete alteration by the heat.

For the purpose of heating the adapter, an extemporaneous furnace is generally made of bricks cut into two or three pieces; but Knight's furnace, fig. 640, has two holes, *g*, made on the opposite sides of the fire-room, to admit the introduction of an adapter of this kind.

When glass adapters are used, they grow so soft by the heat that the expansion of the air within them, which is hindered from escaping by the column of water or quicksilver, in the pneumatic trough over their mouth, that they blow up; hence they require to be wrapped round with thin sheet iron, to preserve their shape.

Earthenware adapters grow porous in the fire, and allow air and steam to pass through them.

Old gun barrels have been used occasionally for this purpose; but the metal is so easily acted upon by other substances that they are not fit for general use.

Lavoisier procured for this purpose a tube of brass turned and bored out of a solid mass; and others have used tubes, obtained in a similar manner, from a rod of copper.

When the vapours are not judged to be sufficiently altered by being made to pass through a single ignited adapter, two or more are used, and the vapours forced to pass from one to another.

## BOTTLES AND FUNNELS.

Glass is now used for keeping the greatest part of chemical subjects and products, especially if liquid, even upon a very large scale: yet there are certain subjects that cannot be kept in it, as quicklime, for this attracting first moisture, and afterwards carbonic acid gas, from the atmosphere, swells so considerably as to break the bottle.

Vegetable powders are also considerably altered by the light that passes through glass, and ought, therefore, to be kept by apothecaries in boxes, instead of bottles.

It is common to keep solid articles, not liable to get moist, in drawers, both in laboratories and in druggists' shops; but this prevents the arrangement of them being altered without

considerable trouble: wooden boxes or stone-ware jars, with covers of the same materials, are far preferable. All jars, of whatever size, which are used for keeping articles, ought to have covers of the same material, instead of the tedious way of tying paper or leather over them.

When bottles have been washed and drained, there still remains in them some traces of water, which, if the bottle is wanted for immediate use, it is frequently very troublesome to remove. Keeping them in a warm stove for hours, is less efficacious than blowing into them the blast of a pair of bellows; but dry, warm, coarse powder of the common stone, called trap, or whinstone, shaken in them, or some slips of dry blotting, or filtering paper, soon absorbs this moisture.

If the substance to be kept in the bottle is altered by the air, and it is desired to empty the bottle of it as far as possible, without the use of an air-pump; a piece of blotting, or filtering paper, or a small pellet of tow, may be soaked in spirit of wine, set on fire and put in the bottle. When it has burned a second or two, and while the flame is yet in its full strength, the bottle is to be quickly and carefully stopped.

### *Stoppered Bottles.*

Glauber's invention of glass stoppers, fitted by grinding in the necks of bottles, is, in many cases, very useful; but cork confines volatile fluids far better than glass stoppers excepting in the case when the cork is corrosible by the liquid.

When, however, a bottle is often opened, or long kept, the cork loses its elasticity, becomes loose, and requires to be changed.

There are some liquids, and even solids, that are almost incoercible by any kind of stopper; and others that cement glass stoppers so that they cannot be removed.

The mucilaginous oils can scarcely be kept in any vessel; Berzelius, in order to secure the oil in his travelling lamp from oozing out, formed the internal part of the neck into a female screw, into which the male screw of the stopper is received; and the joint between the rim of the lamp and the projecting top of the stopper, was secured by a collar of leather soaked in melted bees'-wax.

Iodine, although solid and even crystallized, gets through the joint of glass stoppers, cements them to the neck of the bottle, and will corrode a paper lable on the outside. The case is the same with muriates of red oxide of iron, and several other articles. Chemists endeavour to guard against these untoward effects by greasing or waxing the stoppers, but this will not always succeed.

### *Double-rimmed Bottles.*

The anatomists are much plagued by the volatility of spirit of wine, which escapes from their bottles, however carefully stopped and luted, and leaves their preparations dry. Glauber, in his fifth book on furnaces, 1648, but which in fact treats on the present subject, extended the method the chemists had long used for closing the tops of their tower furnaces, to bottles, and proposed the use of necks with double rims; the groove between which he filled with quicksilver, and then put on a cover. Several attempts have been made to improve this joint, the latest of which is to fill the groove with melted hog's lard: perhaps fusible metal might, by a little dexterity, be run into it. The different expansions, however, of the glass, and whatever substance is used, by the alternation of the seasons, will in all cases tend to open the joint, sufficiently to allow such a subtle liquid to escape. A method resembling that of Berzelius, in respect to oil, is the last proposal; namely, to press a sheet of Indian rubber on the rim of a common bottle by means of a screw, fitted to the neck by a collar.

### *Funnels.*

Besides the common funnels, chemists have occasion for some others, such as the retort funnel, the pipe of which is bent sideways, and must be sufficiently long to reach to the bowl of the retort, so that the liquor may be poured in without soiling the neck.

The capillary funnel is used to convey liquids into the closed end of long, narrow, hollow, glass canes, without soiling the sides: as these funnels are very brittle, they are usually made, when wanted, by heating a piece of a hollow flint glass cane, near one end, and drawing it out suddenly.

Fig. 91, represents a method of filtering a larger quantity of liquid than the funnel will contain, without the necessity of filling it continually; as the liquid contained in the inverted bolthead is supported by the pressure of the atmosphere, and only runs down as the level of the liquid in the funnel getting below its mouth, allows a bubble of air to pass up into its bowl.

If two semicircular pieces of card-paper, with a notch in the middle for the neck of the bolt-head, be laid in the funnel, to rest just above the surface of the liquid, and a narrow mouth bottle used to receive the filtered liquid, the evaporation of the liquid, or the absorption of carbonic acid gas from the air, will be considerably prevented, and this apparatus is well fitted for filtering spiritous tinctures, or caustic alkaline leys.

### *Syphons, or Canes.*

Syphons are vulgarly called cranes, an erroneous pronunciation of cane, the glass-house term for what are frequently called tubes, or rods: they are composed of two legs, the one longer than the other.

Fig. 90.

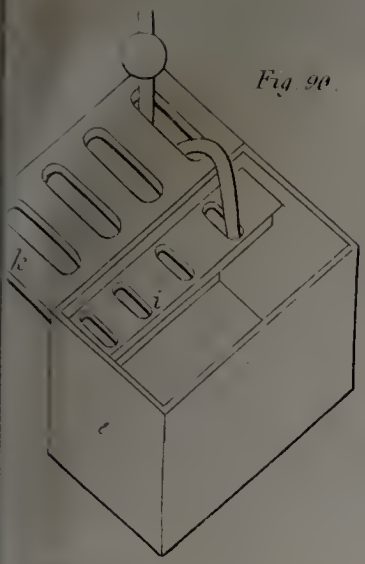



Fig. 91.

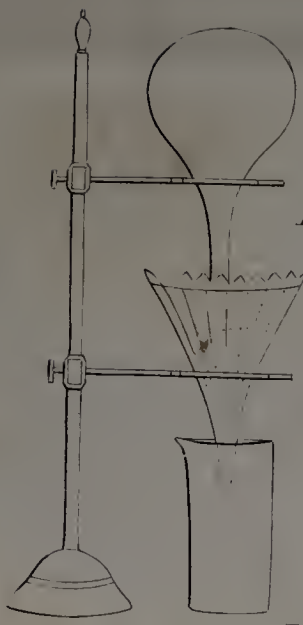


Fig. 92.

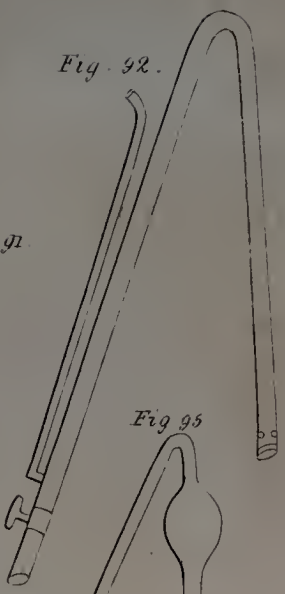


Fig. 95

Fig. 99.

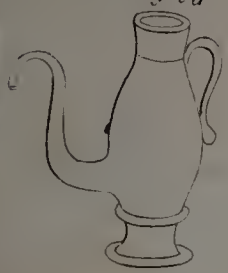


Fig. 93.

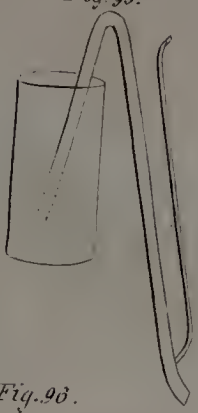


Fig. 94.

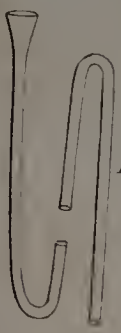


Fig. 96.

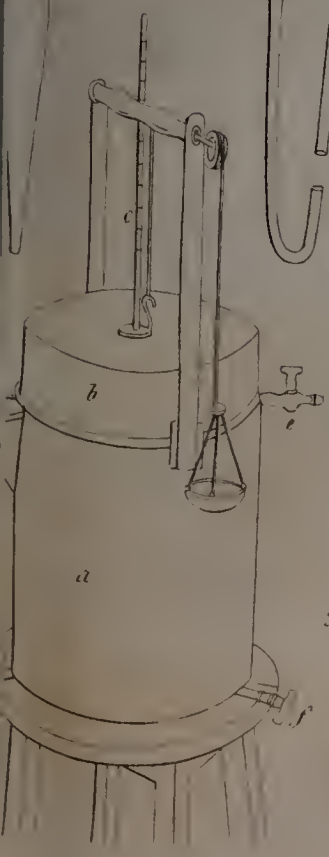
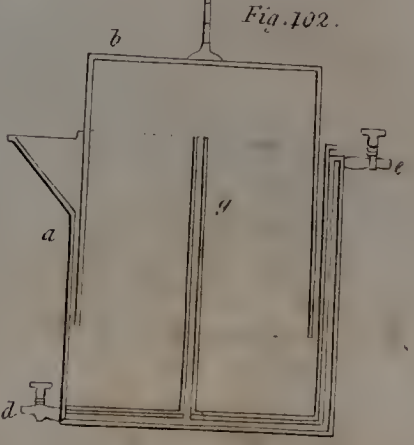



Fig. 102.



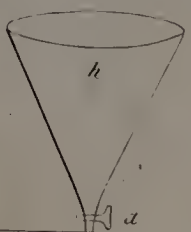



Fig. 101.

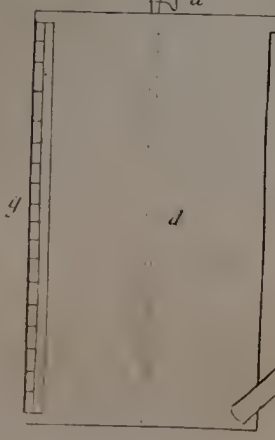



Fig. 100.

The common pewter cane, fig. 92, has a cock at the end of the long leg, and either a sucking pipe, or exhausting syringe, a little above the cock, to raise up the liquid in which the short leg is plunged, over the arch, and so to fill the long leg; after which the liquid will run over by the pressure of the atmosphere.

Several kinds of glass syphons are used in laboratories, either to decant liquids out of bottles, or other vessels, without the necessity of moving them; or to draw liquids off from sediments without disturbing them.

The double glass syphon, fig. 93, has a sucking-pipe, and is a miniature imitation of the common pewter cane; to avoid the danger of drawing any corrosive liquid into the mouth, by a careless use of the sucking-pipe, a bulb is sometimes blown near the top, so that the operator may see plainly when the liquid has reached the top of the sucking-pipe.

The simple cane, or syphon, fig. 94, is used in several different ways.

If the liquid to be decanted is not corrosive, and is contained in a wide-mouthed vessel, the syphon is inverted and filled with some of the liquid, and each end being then stopped with the fingers, the short end is plunged beneath the liquid, and the fingers withdrawn, immediately on which the liquid begins to run off.

If the liquid is corrosive, or contained in a narrow-mouth vessel, the syphon is passed through a notch in the cork, and through another notch there is also passed a short hollow glass cane, through which air is blown by the mouth, or a pair of bellows, joined to the short pipe by the neck of a bladder, or of a bottle of Indian rubber. This blowing of air into the vessel forces the liquid over the arch of the syphon, and causes it to run. The French use this method to decant oil of vitriol, or other acids, out of the carboys, or dames Jeannes, as they call them, in which they come from the manufacturers.

### *Bunten's Syphon.*

The syphon of M. Bunten is shown in fig. 95, where *a*, *b*, is the long branch, with a bulb at *a*, and *c*, *d*, the short branch. This syphon requires neither blowing into the vessel, nor any suction. It is sufficient to fill the long branch, *a*, *b*, and the bulb, *a*, with the liquid, to stop the mouth of the long branch, and to plunge the short branch, *c*, *d*, into the liquid to be decanted. On removing the stopper, the bulb, *a*, in emptying itself, draws off the liquid in contact with the short branch; and though itself is partly empty, the running is unremitting.

### *Hempel's Syphon.*

Another syphon by M. Hempel, a practical chemist at Berlin, is shown at fig. 96. It has the same advantages as that of M. Bunten, and consists of two syphons, one of which is inverted, joined by their short legs. A part of the liquid to be decanted is poured by the funnel, *a*, into the long leg of the inverted syphon, *b*, *c*, which is fitted into the short branch of the proper syphon, *d*, *e*. As soon as the flow commences through the syphon, *d*, *e*, the inverted syphon is withdrawn, and the flow continues.

For the purpose of drawing off the last portions of a liquid, a small glass syringe is very convenient.

### *Wine-Coopers' Cane.*

Another sort of cane is used by the wine-coopers to withdraw the lower part of a liquid for examination.

Fig. 97, represents this cane, which is only a pewter or tin pipe, the upper end of which is made narrow that it may be stopped with the finger: the lower end is still smaller. To use it the upper end is stopped by the finger, and the cane is dipped into the liquid, which is prevented from entering by the resistance of the air; but when it has been dipped to a sufficient depth the finger is withdrawn for a short time, and then being replaced the cane is withdrawn. By again withdrawing the finger from the top, the liquid is allowed to run into a vessel for examination.

### *Separatories.*

There are several kinds of vessels used for separating liquids of different specific gravities.

The common separating funnel, fig. 98, differs from the wine-coopers' cane, only in being enlarged in the middle for the purpose of holding a considerable quantity of liquid. The opening at the bottom of the pipe, which is very small, being closed by the finger or otherwise, the two liquids are poured into the funnel, and the top being stopped with a cork or stopper, they are left for some time to settle; when, the stopper being withdrawn from the top, the heaviest liquid is allowed to run out, and the lightest retained by closing the opening at top with the finger, as soon as the other has passed.

Some funnels of this kind have glass cocks in the pipe; but these are apt to get out of order, and their superior utility is by no means equal to their superior expensiveness.

The spout receiver, fig. 99, is a tall vessel, having a spout on the side, coming out about one-third the height of the vessel from the bottom, and whose bend at top does not rise above two-thirds the height of the vessel. On filling this receiver with two liquids of different specific gravities, and letting them settle, they may be poured out separately.

This vessel is frequently used as a receiver, when vegetables are distilled for their essential oil, as it, like the Italian receiver in fig. 7, allows the water to pass off into another vessel, and retains the oil equally well, whether it floats on water or sinks in it.

A receiver of this kind is sometimes used not only for separating liquids of different specific gravities, but also for sorting the powder of hard substances, which is not soluble in water or other appropriate liquid, into different finenesses. The powder and liquid being put into the receiver and stirred together, are allowed to deposite the grossest particles, and then the liquid, with the finest part yet suspended in it, is poured off into another vessel to settle. Sometimes a stream of water is allowed to run through this receiver while the powder is stirred, and thus the finest particles are carried off and allowed to settle in the vessel into which they are washed.

Another kind of separatory is a squat bottle, fig. 100, with a spout on each side, through which the liquids, when they have separated into layers, may be poured: but it does not seem to possess any advantage over the common apparatus.

## GAS APPARATUS.

It has been already shown that the collection of the aeriform fluids, which are obtainable from substances by heat or admixture, require a peculiar apparatus, and that they are usually collected in bottles, or cylindrical air jars, standing in a trough of water or quicksilver.

These air jars are usually made tall and slender; but there is a great convenience to be provided also with some broad shallow jars, or the glasses used by the confectioners to cover their cates; their breadth causes gases to unite quicker together, and their shallowness is advantageous when the gases are to be transferred by a syphon into another jar, a bladder, or a gas measure.

Bladders are often used as gas holders; they are generally tied on to the brass ferrule of a cock, which furnishes the means of closing them. Silk bags, or those of gauze, varnished with a solution of Indian rubber in highly rectified mineral oil, are also used. These gas holders are frequently more convenient than vessels of a constant size.

### *Leeson's Gas Bottles.*

Similar to these, except in elasticity, are the Indian rubber gas bottles of Mr. Leeson, described in the Quarterly Journal, as made from the bottles of Indian rubber. Those of a black hue generally become very thin and almost transparent by extension; the brown are much less yielding and cannot be extended to the same thinness as the black.

To prepare these bottles they should be boiled in water till they are completely softened, an operation which generally takes a quarter of an hour. When cold, the ferrule of a condensing syringe is firmly tied to the mouth, and air forced into the bottle. A blister first appears, and the whole bottle gradually enlarges; a half pound, or three-quarters of a pound, bottle will generally extend to fourteen or seventeen inches, and sometimes farther, provided it is chosen of a uniform substance, and free from defects.

Having been once gradually and cautiously expanded, these bottles may have a cock fitted to their mouth, and gas forced into them at any time; they are expanded to the same size as before without any danger; and their own elasticity will, on opening the cock, expel the gas, until they are reduced to their original size, or very near it.

These bottles may be used as an oxy-hydrogen blow-pipe, by having a blow-pipe jet screwed to the cock, and should an explosion take place, it would only occasion the loss of the bottle.

## *Watt's Air-holder.*

When the quantity of gas prepared is considerable, it is necessary to be provided with larger vessels than any of those already mentioned to contain it. Such vessels are usually made of tin-plate japanned, or partly of tin-plate and partly of glass, and they are known by the names of gasometers, gas-holders, or air-holders.

Fig. 101, represents Mr. Watt's air-holder. It is made of tin-plate, well japanned, both withinside and without. It may be of any size; the vessel, of which this is a representation, held about two thousand cubic inches. It is a cylindrical vessel, close on all sides, and ought to be pretty strong to resist the pressure of the atmosphere, which tends to force out gas, or to force in air, according to the changes in its density which take place. It is furnished with three openings, *a*, *b*, *c*. The first, *a*, is at the top, the second, *b*, at the side, as high up as possible, the third, *c*, at the bottom. *A* and *b*, are each provided with a cock, the cock, *a*, is soldered into the pipe *d*, which goes to the very bottom of the vessel to which it is soldered, in order to increase the strength of the air-holder. This pipe, *d*, towards its bottom, is perforated with a number of holes. To the extremity of the cock, *b*, a piece of bent pipe, *e*, is ground so as to be air-tight, but to move freely round the extremity of *b*, which is turned up to receive it. And to the extremity of *e*, the long pipe, *f*, is likewise ground so as to be air-tight, yet capable of moving freely. These two tubes by their motion form a universal joint, so as to enable the operator to turn the extremity of the pipe, *f*, any way he thinks proper. The mouth, *c*, consists of a pipe about an inch in diameter, introduced into the vessel near the bottom, at an angle of about 45°. It is provided with a stopper, which screws into it, and shuts it close. *G*, is a hollow glass cane, fixed into the top and bottom of the air-holder, communicating with it, and furnished with a scale of equal parts, the use of which is to show the operator how much gas the vessel contains. It is a large glass conical funnel, made to fit into the upper end of the stop-cock, *a*.

The following is the method of using this air-holder. The first step is to fill it with water. For this the mouth, *c*, must be shut, and both the cocks, *a*, and *b*, opened. Water is then poured into the funnel, which running down the pipe, *d*, makes it escape through the holes in its bottom, and fills the vessel, while the common air makes its escape by the open cock, *b*. When the air-holder is quite full of water the cocks, *a* and *b*, are to be shut, the funnel, *h*, removed, and the stopper of the opening, *c*, removed. As the vessel is completely air-tight, the water cannot make its escape by the opening *c*, because the angle at which it enters the vessel prevents any common air from entering. The mouth of the pipe or cane connected with the apparatus for furnishing gas, being introduced into *c*, the gas rises gradually to the top of the air-holder, and the water runs out by the opening, *c*. When the process is finished this opening is to be stopped; and if the vessel be a good one, oxygen gas, hydrogen gas, or those of coal and oil, may be kept in it for many months without undergoing much alteration.

In order to transfer a portion of the gas out of this air-holder for any particular purpose, the point of the pipe, *f*, is to be introduced into the mouth of the vessel into which the gas is to be transferred, and then a quantity of water is poured into the glass funnel, *h*, which must be replaced for the purpose. The cocks, *a* and *b*, being opened, the water runs down the tube, *d*, and forces the oxygen gas to escape through the pipe, *f*. By this method the whole or any part of the gas may be transferred into other vessels.

If the distance between the funnel, *h*, and the cock, *a*, of the pipe, *d*, is increased by a pipe of two or three feet in length, then, if the funnel is filled as fast as it runs out, the pressure of the water in it will force out the gas, through the pipe, *f*, with considerable velocity.

### *Accum's Gasometer.*

Fig. 102, represents this gasometor. Like the former, it is made of tin plate, is well japanned within and without. *A*, is the outer cylindrical vessel, with a lip at top. Two pipes, *d* and *e*, each fitted with a cock externally, are firmly soldered to the sides of the pail; the pipe, *d*, penetrates at the bottom of the pail, and proceeds to the centre, where it joins the termination of the pipe, *e*, which enters the top of the pail, and proceeds downwards; and, from the place of junction, the upright pipe, *g*, rises through the middle of the pail, a little above the level of its upper rim. The vessel, *b*, is a cylinder, open only at bottom, and of less diameter than the pail into which it is inverted, and can move up and down freely. This cylinder has a solid stem, *c*, which passes through a hole in the wooden cross bar of the frame, round the top of the pail, and serves both to keep the cylinder in a perpendicular direction when moving up and down, and to indicate the quantity of enclosed gas, by the scale of equal parts on its surface. The weight of the cylinder is counterpoised by weights put into a scale, which is connected with the top of the cylinder by a cord and pulley. The outer cylinder has besides an opening through its bottom, closed by a stopper, or cork, *f*, by which the water may be drawn off. The whole apparatus is conveniently supported on a heavy wooden stool.

To use this gas-holder, first let the inner cylinder fall to the bottom of the outer vessel, and pour water into the lip of the latter till it is quite full; then shut the cock, *e*, and open *d*, and connect this cock with the tube that carries the gas immediately from the retort, or other vessel in which it is produced, or, if more convenient, shut *d*, and convey the gas through *e*. The gas rises through the upright tube, *g*, to the top of the cylinder, *b*, which it gradually lifts up; and care must be taken to keep in the scale sufficient weight to allow the cylinder to move with perfect freedom. When all the gas is obtained, shut the cock, *d*, or *e*, and the gas may remain in the air-holder till wanted.

To take out any of it, connect with either of the stop-cocks a bent tube, and insert the mouth of it into a vessel destined to receive the gas; remove some of the weights out of the scale-dish, and open the stop-cock. The weight of the cylinder, *b*, will then press out the gas, and fill the vessel.

As the weight of the cylinder is constantly increasing during the whole of its rise out of the water, it is necessary to be continually adding weights to the scale-dish to compensate for this increase, otherwise the gas will be more and more compressed, and, at last, will cease to enter altogether. Or this increase may be still better compensated, by making the cord pass over a spiral pulley, as in Clayfield's quicksilver gasometer, by means of which, the weight in the scale-dish will act more and more powerfully as the cylinder rises, and thus compensate the increase of its weight.

These gas-holders may be used with a flexible pipe made of Indian rubber as hereafter described, for breathing oxygen gas, or any other as may be directed by the medical attendant; and either this or Watt's air-holder may have a blow-pipe attached to it.

### *Flexible Gas Pipes.*

Mr. Skidmore tried leather pipes in various ways without success.

The guts of the hog and the bullock, in their natural state, answered the purpose tolerably for a short time, but they soon

cracked. When tanned, by being kept some time in an infusion of sumach, they became very porous, notwithstanding they were well impregnated with oils, tallow, or the like.

In order to use Indian rubber for this purpose, a worm of small iron wire, well annealed, was first made of the requisite length, which, in one case, was twelve feet, by coiling the wire as close as could be laid around an iron rod: a covering of tape or ferreting was then wound over this worm to serve as a cover to it.

A bottle of Indian rubber was cut into long narrow strips, by first cutting the bottle into two equal parts, and then reducing them, as near as may be, into the shape of a circular plate, with a sharp pair of tailor's shears. These strips are wound over the covering of tape or ferreting, also in a spiral manner; care being taken to place, as far as is practicable, the fresh cut surfaces in contact with each other, and to draw the strips so tight as to stretch the strips to two, three, or even four times their length. If a single bottle is not sufficient, more must be taken, and, for greater security, a double worm of Indian rubber may be wound one over the other. When this is done, another covering of strong tape, linen tape is preferable, is to be wound spirally over the same, from end to end, and secured by another worm of very strong twine, laid as close, and drawn as tight as possible. The iron rod is then to be withdrawn, the new-formed hose or pipe bent into a hoop by bringing the two ends together, that it may be placed in a boiler of water, and boiled for an hour or two; when it is to be taken out, the outer covering of twine and tape taken off, and the wire worm and its tape or ferreting cover drawn out.

If this pipe is boiled a second time, its size is considerably reduced, which must be noticed when it is desired to join two of them together.

Hose or pipes of this kind have been said to have been manufactured upon glass or metal rods, but Mr. Skidmore was not able to succeed in that way, except upon short pipes not more than four inches long.

The pipes of Indian rubber made upon wire worms as here described, although not very elegant in their outward appearance, are very light, and do not allow the least leakage of gas.

## APPARATUS FOR FITTING VESSELS.

Glass vessels, when issued from the manufacturers, frequently require to have a part of them cut off, or holes drilled in them before they are fit for use.

### *Cutting off the Necks of Glass Vessels.*

In cutting off part of the necks of boltheads, matrasses, bodies, retorts, and similar vessels, several modes have been adopted.

In the first method a piece of thick leather is glued round the neck, at the place where it is to be cut off, and a mark is then made round the neck with the edge of a flint, which is prevented from slipping by the edge of the leather. This trace serves to guide the chemist in proceeding to cut off the piece by a three-cornered file. It often happens, that, as soon as the file has made only a slight furrow round the neck, that it drops off by the least touch; if it does not, the filing must be continued. This method is the best and surest manner of effecting the purpose.

In the second method, a trace is first made by the flint, and a slight furrow by the file, as in the former. A cotton thread dipped in oil of turpentine is then bound round the neck at the furrow, and, being set on fire, the vessel is turned that the neck may be equally heated all round, and as soon as the oil is burned out, the place is touched with a drop of cold water, which generally causes the neck to fall off. Sometimes, however, the vessel becomes cracked on the side, especially if the operator is not accustomed to this work, and has not acquired some dexterity in it.

A third method is, after having made a furrow as before, to take an iron ring that will fit the place, and heating it red hot, apply steadily to the place for a few seconds, and if the neck does not fall off, the ring is removed, and a drop of water put on the place by the finger, which generally succeeds very well, but requires still more address to let all the circumference of the ring touch the glass at once. The chemists who use this method have a stock of different sized rings for this purpose, but some use a pair of tongs, moving on their middle part, and having different sized semicircles at their opposite ends.

The necks of vessels are also cut off by means of a copper wheel, with emery and oil; but this is a peculiar trade, and not used by chemists themselves.

In the first three methods above mentioned the edges of the necks are sharp; and therefore it is necessary to file them, to prevent them from cutting the fingers in fitting them to other vessels.

M. Baumé having occasion for a great number of vessels for the annual course of chemistry which he gave, along with Dr. Macquer, for sixteen years, in each of which there were usually more than two thousand operations and experiments performed by him, as the demonstrator used the following method to cut off the necks of two dozen large boltheads, or other vessels, at once.

A line being stretched along a bench, or plank, the vessels were ranged so that the place where the necks were to be cut were all in the same line, the bowls of the vessels being placed alternately on one side and the other, that they might take up less room. A sufficient quantity of boiled plaster of Paris was then mixed with water, and the spaces between the necks filled up with it, that they might be kept in their places. The plaster being fixed, a saw, such as that used by the stone-masons, but small and light, was then employed, along with freestone grit and water, to cut through all the necks at once.

### *Piercing Glass and Stone-ware Vessels.*

The most simple method of making a hole in the bowl of a glass bolthead, the arch of a retort, or the side of a receiver is, if possible, to pick out a place where there is a bubble in the glass. A very hard steel point is then taken, and worked round in the place, where it generally soon makes a hole down to the bubble; and by a repetition of the process, the hole is completed, which is then enlarged at pleasure, by a rat-tail file. Care must be taken that the file is smaller than the hole, for if it should stick in the hole, the endeavour to disengage it would certainly crack the glass.

Holes are made in the arch of stone-ware retorts, by putting them between the knees, and striking a hard steel point with a hammer, round the place where the hole is to be made, until an opening is effected, which is then enlarged by a rat-tail file, and finished for use by grinding a glass or stone-ware stopper in it, with sand and water, or emery and oil.

Dr. Lewis's method of making such holes for the insertion of barometer canes into glass receivers, was by pasting on the receiver a piece of thick leather, having a hole of the intended size cut in it, then filling the cavity with emery, and turning round in it a steel instrument, with a hollow in the point for retaining the emery, till the glass was worn through.

In Paris, there are workmen who pierce glass and stone-ware, by a hollow drill, which cuts out a circular piece of the vessel. This succeeds very well when the hole is made several lines in diameter, but in making merely pin-holes, the workmen are apt to crack the glass: they succeed very well in making these small holes in stone-ware vessels.

The best method of drilling glass or porcelain, is stated to be the employment of a diamond point, set in brass, worked either by the hand, in an upright drill stock, or in a seal-engraver's engine. The latter way, perhaps, is preferable, as the mill will be more steady; but some thin oil must be used with the diamond.

In London, the chemists seldom have occasion for these operations, as they get them done by workmen who make it their business.

## CHEMICAL LUTES.

The necessity of properly securing the joinings of chemical vessels, to prevent the escape of any of the products of processes or experiments, must be sufficiently apparent. For this purpose lutes are employed, which ought to be of such a nature, as to be impenetrable to the most subtle substance disengaged in the process.

### *Soft Wax.*

This first object of lutes is very well accomplished by melting eight ounces of bees-wax, with about one ounce of turpentine. This lute is very easily managed, sticking very closely to glass, and is very difficultly penetrable. It may be rendered more consistent, and less or more hard, or pliable, by adding different kinds of resinous matters. Though this species of lute answers extremely well for retaining gases and vapours, there are many chemical experiments which produce considerable heat, by which the lute becomes liquified, and consequently the vapours escape.

This soft wax is also used to stop up the small hole left sometimes in receivers, employed in the distillation of substances yielding vapours which are very difficultly condensible. And also to make stoppers for bottles holding acid or volatile alkaline liquids, when stoppered bottles are not at hand.

### *Luting with Paper or Bladder.*

In many cases it is considered sufficient to close the joints with slips of paper, on which some paste has been spread.

Slips of bladder, or gut skins, are also used, being simply moistened and bound round the joint with some twine; as they dry, they fit close and answer well, provided the vapours are not acid or saline.

Bladders close the joints still better, if they are soaked in water until they are quite rotten, stink intolerably, and stick to the fingers: they are then to be formed by the hands into rolls, and applied round the joints.

### *Paste Lute.*

The common paste lute is made of linseed meal, (not ground linseed cake,) beat up with boiled starch. The French chemists use this lute to cover the corks with which bottles are stopped, and then, for greater security, cover it over with blotting-paper, dipped in carpenters' glue.

Cavendish used almond meal, (not ground almond cake,) beat up with a heavy hammer, along with carpenters' glue; this lute will resist the pressure of several inches of water.

### *Lime Lute.*

This is much used, not only for closing the joints of vessels, but also for repairing glass and earthenware vessels, when they have been cracked by accident.

If cheese is used, it should be the driest sort, that it may be grated fine, then mixed with a little water, and some slaked lime: it is then spread quickly on strips of linen cloth, and applied, as it grows hard very quickly.

Some mix the slaked lime with white of egg and a little water, or with carpenters' glue, made sufficiently thin to remain liquid when cold, or with warmed size.

This lute is frequently used to cover the corks with which bottles are stopped; and the French chemists use it to smear over the corks before they are put into the necks of receivers, or other vessels.

This lute is generally capable of being taken off, by being wrapped round for some time with rags wetted with water, to which there may be added occasionally spirit of salt.

### *Fat Lute.*

The following fat lute is the best hitherto discovered for securing the joints of vessels in which substances yielding vapours, very difficultly condensible are distilled, although not without some disadvantages. Very dry clay is put into a mortar, and well beaten with some boiled linseed oil: this lute is sometimes made with amber varnish, instead of boiled oil. To make this varnish, yellow amber is melted in an iron ladle, and mixed with linseed oil. Though the lute prepared with this varnish is supposed to be better than that made with boiled oil, yet, as its additional expense is hardly compensated by its superior quality, it is seldom used, except by those who estimate things by their cost.

The above fat lute is capable of sustaining a very violent degree of heat, is impenetrable by acid and spiritous liquor, and adheres exceedingly well to metal, stone-ware, or glass, provided they have been previously rendered perfectly dry. But if unfortunately any of the liquor in the course of an experiment gets through, either between the glass and the lute, or between the layers of the lute itself, so as to moisten the part, it is extremely difficult to close the opening. This is the chief inconvenience which attends the use of fat lute, and perhaps the only one it is subject to. As it is apt to soften by heat, all the junctures where it is used must be covered with slips of wet bladder applied over the luting, and fixed on by packthread tied round both above and below the joint; the bladder, and consequently the lute below, must be farther secured by a number of turns of packthread all over it. By these precautions we are free from

every danger of accident, and the junctures secured in this manner may be considered as perfectly closed.

It frequently happens, that the figure of the junctures prevents the application of packthread, and it often requires great address to apply the twine without shaking the apparatus, so that, where a number of junctures require luting, several are apt to be displaced while one is secured. In these cases, slips of linen, spread with lime lute, may be substituted, instead of the wet bladder. These are applied while still moist, and very speedily dry, and acquire considerable hardness. These fillets are usually applied likewise over junctures luted together with wax and rosin.

Before applying a lute, all the junctures of the vessels must be accurately and firmly fitted to each other so as not to admit of being moved. If the beak of a retort is to be luted to the neck of a receiver, they ought to fit pretty accurately, otherwise we must fix them by introducing short pieces of soft wood, or of cork. If the disproportion between the two be very considerable, a cork must be fitted into the neck of the receiver, having a circular hole of proper dimensions to admit the beak of the retort. The same precaution is necessary, in adapting bent tubes to the necks of bottles. And when one mouth is intended to admit two or more tubes, the cork must have two or three holes made in it, by a red hot iron, and enlarged by a rat-tail file.

When the whole apparatus is thus solidly joined, so that no part is loose, the application of the lute may be begun; and though this operation may appear extremely simple, yet it requires peculiar delicacy and management, as great care must be taken not to disturb one juncture whilst luting another, and more especially when applying the fillets and twine.

Before beginning any experiment, the closeness of the luting ought always to be previously tried, either by slightly heating the retort, or by blowing in a little air by some of the safety-pipes, as the alteration of pressure will cause a change in the level. If the joints be accurately luted, this alteration of level will be permanent; whereas, if there be the smallest opening in any of the junctures, the liquid will very soon recover its former level.

### *Coating.*

Coating, or corication in the language of grandiloquent philosophers, is the covering of glass and stone-ware vessels with a thin coat of some substance to defend them from sudden alterations of temperature, as, when furnace doors are opened to put in fuel; or to enable glass vessels to keep their form when softened by heat.

The most usual lute is a mixture of about two avoirdupois pounds of clay that resists fire, one pound of some other clay

that is capable of being melted, two pounds of coarse sand, and an ounce of dry horse-dung, or chaff: the whole must be beaten up well with a little water.

To apply this lute, a lump is to be well worked in the hands, and formed into a plate on which the retort is to be placed, and the lute brought up all round it, so as to spread evenly about half an inch thick, as far as the middle of the neck, without any cracks or joinings. If the lute should happen to crack, or any joint be required, the lute must be taken off, and beaten up afresh.

The coating being applied, the retort is set by, that the coating may dry: when dry the outer surface is pared off so as to leave the coating about a quarter of an inch thick.

It is necessary that this coating should be somewhat fusible, that it may not come off in scales. If the fire is not intended to be very fierce, an ounce or two of litharge or red lead may be added to the mixture; or the coating, when dried, is painted over with litharge or red lead ground with linseed-oil.

Some make the mixture for the coating into cream or slip, by adding water, dip the retort into it, and turn it round to cover it equally, the retort is then held over a fire, to dry the coating; and this dipping and drying is repeated until the coating has acquired the desired thickness.

Mr. Willis preferred quicklime for his coating. He boiled two ounces of borax in half a pint of water, and added as much quicklime in fine powder as was sufficient to bring the mixture to the consistence of cream. With a painter's brush he covered the retort with this coating until it was about an eighth of an inch thick. When this coating was dry, he covered it in like manner with a thin paste of slaked lime and linseed-oil. This coating may even be used to mend retorts that crack during any operation.

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In some authors may be found lists of the articles they think necessary to be procured by the chemist at the first fitting up of an experimental laboratory: but, as the views by which different persons are led to make experiments are infinitely various, so it is utterly impracticable to foresee what they may want.

There are, however, too points which cannot be too strongly impressed upon beginners. First, that they should purchase only those materials which they cannot possibly make themselves; since running the processes for obtaining the other articles will not only become a good introduction to the technical part, and show them the use of the different apparatus, but they will acquire a facility in experimenting, and be more con-

fident of the results. He who purchases ready-made preparations, and what are called tests, can only be looked upon as a half-and-half chemist, one degree above the mere reader of chemical books, but still far short of a really practical chemist.

Secondly, that the chemist should purchase no new apparatus, if he can possibly run the process with that which he has already got. A firm adherence to this rule will learn him to choose the most simple way of effecting his purpose. Scheele and Berzelius, the two most successful theoretical experimental chemists, are equally remarkable for the simplicity of their apparatus. Stahl, Lemeri, and Baumé, the three authors to whom practical chemistry is under the highest obligations, have all endeavoured to pursue the same economy, and to obtain their object in the simplest manner.

## THEORY OF CHEMISTRY.

### *Doctrine of Definite Proportions.*

Some substances unite in any proportion, as water and spirit of wine, others only in one proportion, called the point of saturation, as water and common salt: while a third class unite in several determinate proportions of one ingredient, which form a very simple progression, as 1, 1½, 2, 3, 4, 5, the other ingredient being taken as unity. The common salt of tartar, called by some salt of wormwood, and by others prepared kali, contains 275 parts by weight of carbonic acid, united with 594 parts of the base, potasse; whereas the supercarbonate, or bicarbonate, of potasse, called in general aerated kali, contains twice that proportion, that is 550 parts of carbonic acid, united to a similar proportion, or 594 parts of the potasse.

There are, indeed, some cases in which two ingredients unite in extremely different proportions; thus, iron united with about 1-120th of its weight of the carbonaceous element, is stated by Mr. Mushet to form soft cast steel; and, on the other hand, with about twenty-eight times its weight of the same carbonaceous element, it is supposed to form black lead.

It has been found, upon comparing the analogy of a number of substances composed of the same elements, that if the charge of one of these elements be considered as a fixed number, the charges of the other elements combined with it, will also denote the proportions in which they combine with one another, to form other substances, or at least some multiple, or very simple fraction of the same.

Oxygen, on account of its great aptitude to combine with

other bodies, has been generally chosen, by theoretical chemists of the Lavoisierian school, to form the root from which all the other proportional charges of the elements may be calculated.

This union of the elements in certain simple proportions is evident to the eye in the combination of the gases with each other, as also the contraction or expansion of volume that sometimes ensues in consequence of a chemical union taking place. Hence some have supposed that if solid bodies were reduced to a vaporous form, these vapours would unite either in equal volumes, or in certain simple proportions.

Henry, in Journal of Sciences, observes that the law of volumes is, to a certain extent, the expression of a general fact: but in regard to certain elementary substances, which are not known to us separately in a gaseous state, it is entirely a matter of inference that their vapours unite in volumes, which are either equal, or multiples, or submultiples of each other. Nor, if we admit the probability of such combinations, is there any decisive proof that the volumes which have been assigned are actually the true ones.

The theory of atoms is founded upon the general fact that bodies unite in definite proportions: and if we were to set out from a binary compound, whose gaseous elements exist in equal volumes, there would be a perfect accordance between the atomic hypothesis and the theory of volumes.

Some positions which have arisen out of the theory of volumes may or may not be true, without, in the latter case, impeaching its general correctness. Of this nature are the two following propositions:—

1. An increase in the density of a gas is supposed to indicate an increased number of simple atoms associated in the compound atom.

This may have been too hastily deduced, for olefiant gas, a compound of two atoms, is denser than carburetted hydrogen gas, a compound of three atoms. It is also inconsistent with Henry's views of the nitrous compounds.

2. The most simple compounds are the most difficult to be decomposed.

This stands as yet unimpeached:—though, if Mr. Dalton's opinion of nitrous gas being a compound of two atoms, be true, it would present a reasonable objection.

Dr. Henry conceives that nitrous oxide consists of two atoms, and those of nitrous gas of three; though the truth of the opinion is far from being demonstrated.

That the volumes of the elements of these two compounds are as stated by Gay Lussac, Dr. Henry entertains very little doubt: but he asks, do equal volumes of nitrogen gas and oxy-

gen gas contain, as Dalton supposes, equal numbers of atoms, or, as he takes to be more probable, do the same number of atoms exist in one volume of nitrogen gas as in two of oxygen gas?

The word proportion, used by Sir H. Davy, is ambiguous; the numbers 1 and 15 for hydrogen and oxygen were gained from the joint consideration of the weight and volume of the elements of water, those of 15 and 26, for oxygen and nitrogen from weight only; but the numbers for weights and volumes ought to be kept separate.

There are several different calculations of the relative proportions or charges in which the elements combine, of which those of Berzelius, Thenard, and Thomson, are the principal.

Thenard has constructed his table upon the plan the best adapted for practice; and is therefore given in detail; the numbers of Berzelius and Thomson for the elements themselves are only noticed in this place. To these tables are annexed Berzelius' mode of marking the chemical composition in characters. A most capital invention, which may justly be esteemed equal to that of the Arabian figures in arithmetic, or the musical notes. In this chemical algorithm, the numbers to the right of the sign of an element, or the superior figures to the left denote how many proportions, atoms, volumes, or charges, of that element, are contained in the compound. X is used, as in algebra, to denote an unknown quantity, and compounds acting as elements are enclosed in a parenthesis.

### *Thenard's Proportional Numbers.*

Proportional numbers of chemical bodies are those which point the proportion in which they combine with each other.

The following table was calculated by Mr. Despretz, and principally taken from Berzelius' tables.

#### 1. *Oxygen.* O, or ·

The single charge of oxygen is considered as 10,000, and from thence the proportional weight of the single charge of all other bodies is computed.

In the original table of Thenard, as also in those of Berzelius, and other authors, the numbers are given partly in whole numbers, and partly accompanied with decimal fractions of three or four places of figures: but they are now printed in integral numbers, as affording the generality of practical chemists, little accustomed to fractional expressions, a clearer view of the proportions.

#### 2. *Unmetallic Substances, not hitherto divided into two or more simpler Substances*

| 17,705 of *Azote*, Az combined with | forms |
|---|---|
| 10,000 of oxygen. | 27,705 protoxide of azote, Az· |
| 20,000 . . | 37,705 deutoxide of azote, Az· |

| with | forms |
|---|---|
| 30,000 . . | 47,705 hyponitrous acid, Az·· |
| 40,000 . . | 57,705 nitrous acid, Az:. |
| 50,000 . . | 67,705 nitric acid, Az::· |

67,705 of nitric acid combined with so much of any basis as contains 10,000 of oxygen, forms a neutral nitrate.

| with | forms |
|---|---|
| 50,000 of oxygen and 11,243 of water | 78,948 concentrated nitric acid, Az::· H· |
| 15,310 of carbone | 33,015 cyanogen, Az C |
| 3,750 of hydrogen | 21,455 ammoniac, Az $H^3$ |

21,455 of ammoniac is substituted for so much basis as contains 10,000 of oxygen, in the composition of ammoniacal salts.

6,965 of *Bore*, B.

| | |
|---|---|
| 20,000 of oxygen | 26,965 boracic acid, B: |

26,965 of boracic acid combined with so much of any basis as contains 10,000 of oxygen, forms a borate.

| | |
|---|---|
| 20,000 of oxygen and 44,972 of water | 71,937 crystallized boracic acid, B: H·4 |

7,655 of *Carbone*, C.

| | |
|---|---|
| 10,000 of oxygen | 17,655 oxide of carbone, C· |
| 20,000 . . | 27,655 carbonic acid, C· |

27,655 of carbonic acid combined with so much of any basis as contains 10,000 of oxygen, forms a subcarbonate.

55,311 of carbonic acid combined with so much of any basis as contains 10,000 of oxygen, forms a neutral carbonate.

| | |
|---|---|
| 44,013 of chlore | 51,668 protochlorure of carbone, C Cl |
| 66,020 ($1\frac{1}{2}$) . | 73,675 deutochlorure of carbone, 2 C $Cl^3$ |
| 1,243 of hydrogen | 8,898 protocarboned hydrogen, CH |
| 2,486 . . | 10,141 deutocarboned hydrogen, $CH^2$ |

44,013 of *Chlore*, Cl.

| | |
|---|---|
| 10,000 of oxygen | 54,013 protoxide of chlore, Cl· |
| 40,000 . . | 84,013 deutoxide of chlore, Cl:: |
| 50,000 . . | 94,013 chloric acid, Cl::· |

94,013 of chloric acid combined with so much of any basis as contains 10,000 of oxygen, forms a neutral chlorate.

| | |
|---|---|
| 70,000 . . | 114,013 perchloric acid, Ch:::· |

114,013 of perchloric acid combined with so much of any basis as contains 10,000 of oxygen, forms a neutral perchlorate.

| | |
|---|---|
| 17,655 oxide of carbone. . | 61,668 chloroxicarbonic acid, Ch C· |
| 1,243 of hydrogen | 45,256 hydrochloric acid, Ch H |

45,256 of hydrochloric acid combined with so much of any basis as contains 10,000 of oxygen, forms a neutral hydrochlorate.

1,243 of *Hydrogen*, H.

| | |
|---|---|
| 10,000 oxygen . | 11,243 water H· |
| 20,000 . . | 21,243 deutoxide of hydrogen, H: |

156,223 of *Iodine*, I.

| | |
|---|---|
| 50,000 oxygen . | 206,223 iodic acid, I::· |

206,232 of iodic acid combined with so much of any basis as contains 10,000 of oxygen, forms a neutral iodate.

| | |
|---|---|
| 1,243 hydrogen. | 157,466 hydroiodic acid, IH |

157,466 of hydroiodic acid combined with so much of any basis as contains 10,000 of oxygen, forms a neutral hydroiodate.

| | |
|---|---|
| 5,901 azote. ($\frac{1}{3}$) . | 163,123 iodure of azote, 3 I Az |

19,615 of *Phosphorus*, P.

| with | forms |
|---|---|
| 7,500 oxygen ($\frac{1}{2}$) | 26,615 hypophosphorous acid, 2 PO |
| 15,000 ($1\frac{1}{2}$) . | 34,615 phosphorous acid, 2 $PO^3$ |

34,615 of phosphorous acid with so much of any basis as contains 10,000 of oxygen, forms a neutral phosphate.

| | |
|---|---|
| 25,000 ($2\frac{1}{2}$) . . | 44,615 phosphoric acid, 2 $PO^5$ |

44,615 of phosphoric acid with so much of any basis as contains 10,000 of oxygen, forms a neutral phosphate.

As for the sub-phosphates, the acidulous phosphates, or the acid phosphates, the number 44,615 of phosphoric acid must be multiplied by $\frac{2}{3}$, $\frac{3}{4}$, or by 2, the quantity of the base remaining the same.

| | |
|---|---|
| 66,020 chlore ($1\frac{1}{2}$) | 85,635 proto chlorure of phosphorus 2 P $Cl^3$ |
| 110,033 ($2\frac{1}{2}$) . | 129,648 deuto chlorure of phosphorus, 2 P $Cl^5$ |

49,591 of *Selenium*, Se.

| | |
|---|---|
| 20,000 oxygen . | 69,591 selenic acid, Se· |

69,591 of selenic acid with as much of any basis as contains 10,000 of oxygen, forms a neutral seleniate.

| | |
|---|---|
| 1,243 hydrogen | 50,634 hydro selenic acid, SH |

20,000 of *Sulphur*, S.

| | |
|---|---|
| 10,000 of oxygen | 30,000 hyposulphurous acid, S· |
| 20,000 . . | 40,000 sulphurous acid, S: |

40,000 of sulphurous acid, with so much of any basis as contains 10,000 of oxygen, forms a neutral sulphate.

| | |
|---|---|
| 25,000 ($2\frac{1}{2}$) . | 45,000 hyposulphuric acid, 2 S $O^5$ |

90,000 of hyposulphuric acid, with so much of any basis as contains 10,000 of oxygen, forms a neutral hyposulphate.

| | |
|---|---|
| 30,000 . . | 50,000 sulphuric acid, S:· |

50,000 of sulphuric acid, with so much of any basis as contains 10,000 of oxygen, forms a neutral sulphate.

| | |
|---|---|
| 30,000 oxygen and 11,243 of water | 61,243 concentrated sulphuric acid, S:· H· |
| 1,243 of hydrogen | 21,243 hydro-sulphuric acid, S H |

21,243 of hydro-sulphuric acid, with so much of any base as contains 10,000 of oxygen, forms a sub hydro-sulphate. It takes 42,486 of hydro-sulphuric acid to form saturated hydro-sulphates.

### 3. *Metallic Substances not hitherto divided into two or more simpler substances.*

11,410 of *Aluminium*, Al

| | |
|---|---|
| 10,000 oxygen | 21.410 alumine, Al· |

53,760 of *Antimony*, Sb.

| | |
|---|---|
| 10,000 of oxygen | 63,760 protoxide of antimony, Sb· |
| 13,333 ($1\frac{1}{3}$) . | 67,090 deutoxide of antimony, 3 Sb $O^4$ |
| 16,663 ($1\frac{2}{3}$) . | 70,420 tritoxide of antimony, 3 Sb $O^5$ |
| 44,013 chlore . | 97,773 proto chlorure of antimony, Sb Cl |
| 20,000 sulphur . | 73,760 proto sulphure of antimony, Sb S |
| 156,223 iode . | 209,983 proto-iodure of antimony, Sb I |

47,038 of *Arsenic*, As.

| | |
|---|---|
| 15,000 of oxygen ($1\frac{1}{2}$) | 62,038 oxide of arsenic, or arsenous acid, 2 As $O^3$ |
| 25,000 ($2\frac{1}{2}$) . | 72,038 arsenic acid, 2 As $O^5$ |

72,038 of arsenic acid with so much of any basis as contains 10,000 of oxygen, forms a neutral arseniate.

| with | | forms | |
|---|---|---|---|
| 20,000 | of sulphur | 67,038 | proto sulphure of arsenic, As S |
| 30,000 | . . | 77,038 | deuto sulphure of arsenic, 2 As $S^3$ |
| 66,020 | chlore ($1\frac{1}{2}$) | 113,058 | chlorure of arsenic, 2 As $Cl^3$ |
| 234,334 | iode ($1\frac{1}{2}$) | 281,342 | iodure of arsenic, 2 As $I^3$ |

85,690 of *Barium*, Ba.

| | | | |
|---|---|---|---|
| 10,000 | oxygen . | 95,690 | barytes, Ba· |
| 20,000 | . . | 105,690 | deutoxide of barium, Ba: |
| 20,000 | sulphur . | 105,690 | proto-sulphure of barium, Ba S |
| 44,010 | chlore . | 129,700 | chlorure of barium, Ba Cl |
| 156,223 | iode . | 141,913 | iodure of barium, Ba I |

88,690 of *Bismuth*, Bi.

| | | | |
|---|---|---|---|
| 10,000 | oxygen . | 98,690 | oxide of bismuth, Bi· |
| 20,000 | sulphur . | 108,690 | sulphure of bismuth, Bi S |
| 44,010 | chlore . | 132,700 | chlorure of bismuth, Bi Cl |
| 156,223 | iode . | 244,913 | iodure of bismuth, Bi I |

69,680 of *Cadmium*, Cm.

| | | | |
|---|---|---|---|
| 10,000 | oxygen . | 79,680 | oxide of cadmium, Cm· |
| 20,000 | sulphur . | 89,680 | sulphur of cadmium, Cm S |

25,600 of *Calcium*, Ca.

| | | | |
|---|---|---|---|
| 10,000 | oxygen . | 35,600 | lime, Ca· |
| 20,000 | . . | 45,600 | deutoxide of calcium, Ca: |
| 20,000 | sulphur . | 45,600 | proto sulphure of calcium, Ca S |
| 44,013 | chlore . | 69,613 | chlorure of calcium, Ca Cl |
| 156,223 | iode . | 181,823 | iodure of calcium, Ca I |

57,470 of *Cerium*, Ce.

| | | | |
|---|---|---|---|
| 10,000 | oxygen . | 67,470 | protoxide of cerium, Ce· |
| 15,000 | ($1\frac{1}{2}$) . | 72,470 | deutoxide of cerium, 2 Ce $O^3$ |
| 44,013 | chlore . | 101,483 | proto chlorure of cerium, Ce Cl |

35,180 of *Chromium*, Ch.

| | | | |
|---|---|---|---|
| 15,000 | oxygen ($1\frac{1}{2}$) | 50,180 | oxide of chromium, 2 Ch $O^3$ |
| 20,000 | . . | 55,180 | deutoxide of chromium, Ch: |
| 30,000 | . . | 65,180 | chromic acid, Ch:· |

65,180, of chromic acid with so much of any basis as contains 10,000 oxygen, forms a neutral chromate.

36,900 of *Cobalt*, Co.

| | | | |
|---|---|---|---|
| 10,000 | oxygen . | 46,900 | protoxide of cobalt, Co· |
| 15,000 | ($1\frac{1}{2}$) . | 51,900 | deutoxide of cobalt, 2 Co $O^3$ |
| 44,013 | chlore . | 80,913 | protochlorure of cobalt, Co Cl |

182,310 of *Columbium*, Ta.

| | | | |
|---|---|---|---|
| 10,000 | oxygen . | 192,310 | columbic acid, Ta· |

192,310 of columbic acid with so much of any basis as contains 10,000 of oxygen, forms a neutral columbate.

79,140 of *Copper*, Cu.

| | | | |
|---|---|---|---|
| 10,000 | oxygen . | 89,140 | protoxide of copper, Cu· |
| 20,000 | . . | 99,140 | deutoxide of copper, Cu: |
| 40,000 | . . | 110,140 | tritoxide of copper, Cu:: |
| 20,000 | sulphur . | 99,140 | proto sulphure of copper, Cu S |
| 40,000 | . . | 119,140 | deuto sulphure of copper, Cu $S^2$ |
| 44,013 | chlore . | 123,153 | proto chlorure of copper, Cu Cl |
| 88,026 | . . | 167,166 | deuto chlorure of copper, Cu $Cl^2$ |
| 156,223 | iode . | 235,363 | iodure of copper, Cu I |

22,080 of *Glucinium*, Be.

| with | forms |
|---|---|
| 10,000 oxygen . | 32,080 glucine, Be· |

248,600 of *Gold*, Au.

| | |
|---|---|
| 10,000 oxygen . | 258,600 protoxide of gold, Au· |
| 30,000 . . | 278,600 deutoxide of gold, Au: · |
| 40,000 sulphur . | 288,600 sulphure of gold, Au $S^2$ |
| 132,039 chlore . | 380,639 chlorure of gold, Au $Cl^3$ |

60,000 of *Iridium*, Ir.

| | |
|---|---|
| 20,000 sulphur . | 60,000 sulphure of iridium, Ir S |

33,920 of *Iron*, Fe.

| | |
|---|---|
| 10,000 oxygen . | 43,920 protoxide of iron, Fe· |
| 15,000 . . | 48,920 peroxide of iron, 2 Fe $O^3$ |
| 20,000 sulphur . | 53,920 proto sulphure of iron, Fe S |
| 40,000 . . | 73,920 per sulphure of iron, Fe $S^2$ |
| 44,013 chlore . | 77,933 proto chlorure of iron, Fe Cl |
| 156,223 iode . | 190,143 proto iodure of iron, Fe I |

129,450 of *Lead*, Pb.

| | |
|---|---|
| 10,000 oxygen . | 139,450 protoxide of lead, Pb· |
| 15,000 ($1\frac{1}{2}$) . | 144,450 deutoxide of lead, 2 Pb $O^3$ |
| 20,000 . | 149,450 tritoxide of lead, Pb: |
| 20,000 sulphur . | 149,450 proto sulphure of lead, Pb S |
| 44,013 chlore . | 173,463 chlorure of lead, Pb Cl |
| 156,223 iode . | 285,673 iodure of lead, Pb I |

12,780 of *Lithium*, L.

| | |
|---|---|
| 10,000 oxygen . | 22,780 lithine, L· |
| 44,013 chlore . | 56,793 chlorure of lithium, L Cl |

15,840 of *Magnesium*, Mg.

| | |
|---|---|
| 10,000 oxygen . | 25,840 magnesia, Mg· |
| 44,013 chlore . | 59,853 chlorure of magnesium, Mg Cl |
| 156,223 iode . | 172,063 iodure of magnesium, Mg I |

35,580 of *Manganese*, Mn.

| | |
|---|---|
| 10,000 oxygen . | 45,580 protoxide of manganese, Mn |
| 15,000 ($1\frac{1}{2}$) . | 50,580 deutoxide of manganese, 2 Mn: $O^3$ |
| 20,000 . . | 55,580 peroxide of manganese, Mn: |
| 44,013 chlore . | 79,593 chlorure of manganese, Mn Cl |

59,680 of *Molybdene*, Mo.

| | |
|---|---|
| 10,000 oxygen . | 69,680 oxide of molybdene, Mo· |
| 20,000 . . | 79,680 molybdene acid, Mo: |
| 30,000 . . | 89,680 molybdic acid, Mo:· |

89,680 of molybdic acid with so much of any base as contains 10,000 of oxygen, forms a neutral molybdate.

| | |
|---|---|
| 40,000 sulphur . | 99,680 sulphure of Molybdene, Mo $S^2$ |

36,970 of *Nickel*, Ni.

| | |
|---|---|
| 10,000 . . | 46,970 protoxide of nickel, Ni· |
| 15,000 ($1\frac{1}{2}$) . | 51,970 peroxide of nickel, 2 Ni $O^3$ |
| 44,013 chlore . | 80,983 chlorure of nickel, Ni Cl |

*Osmium*, proportional number unknown.

70,380 of *Palladium*, Pa.

| | |
|---|---|
| 10,000 oxygen . | 80,386 protoxide of palladium, Pa· |
| 20,000 sulphur . | 90,380 sulphure of palladium, Pa S |
| 44,013 chlore . | 114,393 chlorure of palladium, Pa Cl |

121,520 of *Platinum*, Pt.

| | |
|---|---|
| 10,000 oxygen . | 131,520 protoxide of platinum, Pt· |

| with | | forms |
|---|---|---|
| 20,000 | . . | 141,520 deutoxide of platinum, Pt: |
| 88,026 | chlore . | 209,546 chlorure of platinum, $Pt Cl^2$ |
| 20,000 | sulphur . | 141,520 proto sulphure of platinum, Pt S |
| 40,000 | . . | 101,520 deuto sulphure of platinum, $Pt S^2$ |

48,990 of *Potassium*, K.

| | | |
|---|---|---|
| 10,000 | oxygen . | 58,990 potasse, K· |
| 30,000 | . . | 78,990 peroxide of potassium, K:· |
| 44,013 | chlore . | 93,003 chlorure of potassium, K Cl |
| 156,220 | iode . | 205,210 iodure of potassium, KI |
| 20,000 | sulphur . | 68,990 proto sulphure of potassium, KS |

253,160 of *Quicksilver*, Hd.

| | | |
|---|---|---|
| 10,000 | oxygen . | 263,160 protoxide of quicksilver, Hd· |
| 20,000 | . . | 273,160 deutoxide of quicksilver, Hd: |
| 20,000 | sulphur . | 273,160 proto sulphure of quicksilver, Hd S |
| 40,000 | . . | 293,160 deuto sulphure of quicksilver, $Hd S^2$ |
| 44,013 | chlore . | 297,173 chlorure of quicksilver, Hd Cl |
| 88,026 | . . | 341,186 deuto chlorure of quicksilver, $Hd Cl^2$ |
| 156,220 | iode . | 409,380 iodure of quicksilver, HI |
| 312,440 | . . | 565,600 deuto iodure of quicksilver, $HI^2$ |

150,010 of *Rhodium*, R.

| | | |
|---|---|---|
| 10,000 | oxygen . | 160,010 protoxide of rhodium, R· |
| 20,000 | . . | 170,010 deutoxide of rhodium, R: |
| 30,000 | . . | 180,010 tritoxide of rhodium, R:· |
| 40,000 | sulphur . | 190,010 sulphure of rhodium, $RS^2$ |

9,890 of *Silicium*, Si.

| | | |
|---|---|---|
| 10,000 | oxygen . | 19,890 silica, Si· |

135,160 of *Silver*, Ag.

| | | |
|---|---|---|
| 10,000 | oxygen . | 145,160 oxide of silver, Ag· |
| 20,000 | sulphur . | 155,160 sulphure of silver, Ag S |
| 44,013 | chlore . | 179,173 chlorure of silver, Ag Cl |
| 156,223 | iode . | 291,383 iodure of silver, Ag I |

29,090 of *Sodium*, Na.

| | | |
|---|---|---|
| 10,000 | oxygen . | 39,090 soda, Na· |
| 15,000 | $(1\frac{1}{2})$ . | 45,090 peroxide of sodium, $2 Na O^3$ |
| 20,000 | sulphur . | 49,090 proto sulphure of sodium, Na S |
| 44,013 | chlore . | 73,103 chlorure of sodium, Na Ch |
| 156,223 | iode . | 185,313 iodure of sodium, Na I |

54,730 of *Strontium*, Sr.

| | | |
|---|---|---|
| 10,000 | oxygen . | 64,730 strontian, Sr· |
| 20,000 | . . | 74,730 deutoxide of strontium, Sr: |
| 20,000 | sulphur . | 74,730 proto sulphure of strontium, Sr S |
| 44,013 | chlore . | 98,743 chlorure of strontium, Sr Cl |
| 156,223 | iode . . | 210,953 iodure of strontium, Sr I |

40,320 of *Tellurium*, Te.

| | | |
|---|---|---|
| 10,000 | oxygen . | 50,320 oxide of tellurium, Te· |
| 44,013 | chlore . | 88,333 chlorure of tellurium, Te Cl |
| 1,243 | hydrogen . | 41,563 telluretted hydrogen, Te H |

73,530 of *Tin* Sn.

| | | |
|---|---|---|
| 10,000 | oxygen . | 83,530 protoxide of tin, Sn· |
| 20,000 | . . | 93,530 deutoxide of tin, Sn: |
| 20,000 | sulphur . | 93,530 proto sulphure of tin, Sn S |
| 40,000 | . . | 113,530 per sulphure of tin, $Sn S^2$ |
| 44,013 | chlore . | 117,543 proto chlorure of tin, Sn Cl |

with forms

88,026 . . 161,556 deuto chlorure of tin $Sn\ Cl^2$
156,223 iode . . 229,753 iodure of tin, Sn I

*Titanium*, Ti. proportional number unknown.

120,770 of *Tungsten*, W.

20,000 oxygen . 140,770 oxide of tungsten, W:
30,000 . . 150,770 tungstic acid, W:·

150,770 of tungstic acid, with so much of any basis as contains 10,000 oxygen, forms a tungstate.

40,000 sulphur . 160,770 sulphure of tungsten, $WS^2$

157,340 of *Uranium*, U.

10,000 oxygen . 167,340 protoxide of urane, U·
15,000 ($1\frac{1}{2}$) . 172,340 deutoxide of urane, $2\ U\ O^3$

40,260 of *Yttrium*, Y.

10,000 oxygen . 50,260 yttria, Y·

40,320 of *Zinc*, Zn.

10,000 oxygen . 50,320 oxide of zinc, Zn·
20,000 sulphur . 60,320 sulphur of zinc, Zn S.
44,013 chlore . 84,333 chlorine of zinc, Zn Cl
156,223 iodc . 196,543 iodure of zinc, Zn I

46,250 of *Zirconium*, Zr.

10,000 oxygen . 56,250 zircone, Zr·

64,115 Acetic acid, A-
150,950 Benzoic acid, B-
72,780 Citric acid, C-
46,390 Formic acid, F·
79,180 Gallic acid, G-
33,960 Hydro-cyanic acid, P-
91,160 Malic acid, Ml-
333,333 Margaric acid, Mg-
131,830 Mucic acid, Mu-
333,333 Oleic acid, Ol-
45,170 Oxalic acid, O-
62,780 Succinic acid, S-
83,450 Tartaric acid, T-

All respectively with so much of any base as contains 10,000 of oxygen, form a neutral salt.

11,243· *Water*, H·

| | |
|---|---|
| 21,410 alumine, Al· | 32,653 hydrate of alumine, Al· H· |
| 95,690 barytes, Ba· | 106,933 hydrate of barytes, Ba· H· |
| 35,600 lime, Ca· | 46,843 hydrate of lime, Ca· H· |
| 99,140 deutoxide of copper, Cu: | 10,383 hydrate of deutoxide of copper, Cu: H· |
| 83,530 protoxide of tin, Sn· | 94,773 hydrate of protoxide of tin, Sn· H· |
| 43,920 protoxide of iron, Fe· | 55,163 hydrate of protoxide of iron, Fe· H· |
| 22,780 lithine, L· | 34,023 hydrate of lithine, L· H· |
| 25,840 magnesia, Ma· | 37,083 hydrate of magnesia Ma· H· |
| 45,580 protoxide of manganese, Mn· | 56,823 hydrate of protoxide of manganese, Mn· H· |
| 58,990 potasse, K· | 70,233 hydrate of potasse, K· H· |
| 39,090 soda, Na· | 50,333 hydrate of soda, Na· H· |
| 64,730 strontia, Sr· | 75,973 hydrate of strontia, Sr· H· |
| 50,320 oxide of zinc, Zn· | 61,583 hydrate of oxide of zinc, Zn· H· |

In these hydrates, which are the greatest part of those in which the proportion of water has been accurately determined, the quantity of oxygen in the oxide is equal to that in the water, on the Lavoisierian hypothesis.

It is probable that there exists subhydrates which contain only half this proportion of water; and superhydrates which contain twice this proportion or even more. The crystallized hydrates of potasse, soda, barytes, and strontia are probably super hydrates. Berzelius is of opinion that crystallized hydrate of barytes contains one proportion of barytes and nine of water, or $Ba\cdot + 9\ H\cdot$

| with | forms |
|---|---|
| 64,110 dry acetic acid, $A-$ | 75,353 crystallized acetic acid, $A-H\cdot$ |
| 23,453 dry tartaric acid, $T-$ | 94,693 crystallized tartaric acid, $T-H\cdot$ |
| 113,680 dry acetate of deutoxide of copper, $A-Cu:$ | 124,923 crystallized acetate of deutoxide of copper, $A-Cu:+H\cdot$ |
| 76,754 dry bicarbonate of ammoniac, $2\ C:+Az\ H^3$ | 87,997 crystallized bicarbonate of ammoniac, $2\ C:+Az\ H^3+H\cdot$ |
| 114,300 dry bicarbonate of potasse, $2\ C:K\cdot$ | 125,543 crystallized bicarbonate of potasse, $2\ C:K\cdot+H\cdot$ |
| 94,400 dry bicarbonate of soda, $2\ C:Na\cdot$ | 105,643 crystallized bicarbonate of soda, $2\ C:Na\cdot+H\cdot$ |
| 89,149 dry nitrate of ammoniac, $Az:::\cdot+Az\ H^3$ | 100,392 crystallized nitrate of ammoniac, $Az:::\cdot+Az\ H^3+H\cdot$ |
| 149,350 dry bi-oxalate of potasse, $2\ O-K\cdot$ | 160,593 crystallized bi-oxalate of potasse, $2\ O-K\cdot+H\cdot$ |
| 110,684 dry bi-phosphate of ammoniac, $2\ (P\ O^{2\cdot5})+Az\ H^3$ | 144,413 crystallized bi-phosphate of ammoniac, $2\ (P\ O^{2\cdot5})\ Az\ H^3+H\cdot$ |
| 225,850 dry bi-tartrate of potasse, $2\ T-K\cdot$ | 237,155 crystallized bi-tartrate of potasse, $2\ T-K\cdot+H\cdot$ |

16,864 Water, $1\cdot5\ H\cdot$

| | |
|---|---|
| 48,920 peroxide of iron, $Fe\ O^{1\cdot5}$ | 65,784 hydrate of peroxide of iron, $Fe\ O^{1\cdot5}+1\cdot5\ H\cdot$ |
| 93,482 dry arseniate of ammoniac, $As\ O^{2\cdot5}+Az\ H^3$ | 110,346 crystallized arseniate of ammoniac, $As\ O^{2\cdot5}+Az\ H^3+1\cdot5\ H\cdot$ |
| 66,064 dry phosphate of ammonic, $P\ O^{2\cdot5}+Az\ H^3$ | 82,928 crystallized phosphate of ammoniac, $P\ O^{2\cdot5}+Az\ H^3\ 1\cdot5\ H\cdot$ |

22,480 Water, $2\ H\cdot$

| | |
|---|---|
| 72,780 dry citric acid, $C-$ | 95,260 crystallized citric acid, $C-+2\ H\cdot$ |
| 203,066 dry biarseniate of potasse, $2\ (As\ O^{2\cdot5}+K\cdot$ | 225,552 crystallized biarseniate of potasse, $2\ (As\ O^{2\cdot5})+K\cdot+2\ H\cdot$ |
| 185,690 dry hypo-sulphate of barytes, $S\ O^{2\cdot5}+Ba\cdot$ | 207,976 crystallized hypo-sulphate of barytes, $S\ O^{2\cdot5}+Ba\cdot+2\ H\cdot$ |
| 148,230 dry biphosphate of potasse, $2\ (P\ O^{2\cdot5})+K\cdot$ | 170,716 crystallized biphosphate of potasse, $2\ (P\ O^{2\cdot5})+K\cdot+2\ H\cdot$ |

| with | forms |
|---|---|
| 71,444 dry sulphate of ammoniac, $S:\cdot + Az\ H^3$ | 93,930 crystallized sulphate of ammoniac, $S:\cdot + Az\ H^3 + 2\ H\cdot$ |
| 85,600 dry sulphate of lime, $S:\cdot Ca\cdot$ | 108,080 hydrated crystals of sulphate of lime, $S:\cdot Ca\cdot + 2\ H\cdot$ |

33,729 Water, 3 H·

| | |
|---|---|
| 203,560 dry acetate of lead, $A-Pb\cdot$ | 237,289 crystallized acetate of lead, $A-Pb\cdot + 3\ H\cdot$ |
| 165,520 dry biarseniate of ammoniac, $2\ (As\ O^{2\cdot5}) + Az\ H^3$ | 199,249 crystallized biarseniate of ammoniac, $2\ (As\ O^{2\cdot5}) + Az\ H^3 + 3\ H\cdot$ |
| 239,710 dry quadroxalate of potasse, $4\ O-K\cdot$ | 273,439 crystallized quadroxalate of potash, $4\ O-K\cdot + 3\ H\cdot$ |
| 110,684 dry biphosphate of ammoniac, $2\ (PO^{2\cdot5}) + Az\ H^3$ | 144,413 crystallized biphosphate of ammoniac, $2\ (PO^{2\cdot5}) + Az\ H^3 + 3\ H\cdot$ |

44,972 Water, 4 H·

| | |
|---|---|
| 183,166 dry biarseniate of soda, $2\ (As\ O^{2\cdot5}) + Na\cdot$ | 228,138 crystallized biarseniate of soda, $2\ (As\ O^{2\cdot5}) + Na\cdot + 4\ H\cdot$ |
| 128,330 dry biphosphate of soda, $2\ (PO^{2\cdot5}) + La\cdot$ | 173,302 crystallized biphosphate of soda, $2\ (PO^{2\cdot5}) + Na\cdot + 4\ H\cdot$ |

56,215 Water, 5 H·

| | |
|---|---|
| 149,140 dry sulphate of deutoxide of copper, $S:\cdot Cu:$ | 205,355 crystallized sulphate of deutoxide of copper, $S:\cdot Cu: + 5\ H\cdot$ |
| 100,320 dry sulphate of zinc, $S:\cdot Zn\cdot$ | 156,355 crystallized sulphate of zinc, $S:\cdot Zn\cdot + 5\ H\cdot$ |

78,701 Water, 7 H·

| | |
|---|---|
| 93,920 dry sulphate of protoxide of iron, $S:\cdot Fe\cdot$ | 172,621 crystallized sulphate of protoxide of iron, $S:\cdot Fe\cdot + 7\ H\cdot$ |
| 75,840 dry sulphate of magnesia, $S:\cdot Mg\cdot$ | 154,541 crystallized sulphate of magnesia, $S:\cdot Mg + 7\ H\cdot$ |
| 96,970 dry sulphate of nickel, $S:\cdot N\ 2\cdot$ | 175,671 crystallized sulphate of nickel, $S:\cdot Ni\cdot + 7\ H\cdot$ |

112,430 Water, 10 H·

| | |
|---|---|
| 66,745 dry carbonate of soda, $C:Na\cdot$ | 179,175 crystallized carbonate of soda, $C:Na\cdot + 10\ H\cdot$ |
| 89,090 dry sulphate of soda, $S:\cdot Na\cdot$ | 201,520 crystallized sulphate of soda, $S:\cdot Na\cdot + 10\ H\cdot$ |

134,916 Water, 12 H·

| | |
|---|---|
| 111,128 dry arseniate of soda, $As\ O^{2\cdot5} + Na\cdot$ | 246,044 crystallized arseniate of soda, $As\ O^{2\cdot5} + Na\cdot + 12\ H\cdot$ |
| 83,710 dry phosphate of soda, $PO^{2\cdot5} + Na\cdot$ | 218,626 crystallized phosphate of soda, $PO^{2\cdot5} + Na\cdot + 12\ H\cdot$ |

In this table the proportional number or charge of any substance is estimated, so that it requires 10,000 of oxygen to reduce it to a protoxide, except in the case of bore, phosphorus, iode, arsenic, chromium, and tungsten, for in these cases, that number has been chosen which will enable their acids to saturate a base containing 10,000 of oxygen. By this arrangement, a very considerable degree of facility in making calculations in practical chemistry has been obtained.

To obtain the proportional numbers of the neutral salts, it is therefore only necessary to add the number of the acid, to that of the base that contains 10,000 of oxygen, as 64,110 acetic acid, with 139,450 protoxide of lead, forms 203,560 dry acetate of lead, which, in its hydrated or crystalline state, is called sugar of lead, or lead saccharum.

The proportional numbers of the neutralized deutoxides is obtained by observing that they require so much the larger proportion of acid as they contain oxygen, as 263,160 protoxide of quicksilver, containing 10,000 of oxygen, requires only 50,000 of dry sulphuric acid for its neutralization, but 273,160 deutoxide of quicksilver, containing an extra 10,000 of oxygen, requires twice as much, or 100,000 of dry sulphuric acid to neutralize it. In general, super-salts, or those with excess of acid, contain twice as much acid as neutral salts; and sub-salts, or those with excess of base, contain only half as much acid as neutral salts; but there are many exceptions to this rule, and it is always the safest plan to consult the particular article.

### *Use of the Proportional Numbers.*

This is best shown by examples.

1. How much charcoal, supposing it composed of pure carbone, is necessary to reduce a pound of the protoxide of any metal, as of iron, so that the charcoal may, by uniting with the oxygen gas, form carbonic oxide.

17,655 carbonic oxide gas contains 10,000 of oxygen, and 43,920 black oxide of iron the same quantity; consequently, 7,655 parts of charcoal, will absorb all the oxygen of 43,920 parts of black oxide of iron, and form carbonic oxide gas. Therefore, rejecting the three right-hand figures, as subtleties of little use in practice, say, if 44 black oxide of iron requires 8 of charcoal, 1 pound, or 7000 grains, of the metallic oxide, will require 1272 grains, or three ounces, three quarters, and fifteen grains. If it was intended to produce carbonic acid gas, which contains twice as much oxygen, it would, of course, be only necessary to use half that quantity of charcoal.

2. In what proportion must nitrate of lime, and sub-carbo

nate of potasse be mixed, that there may occur a complete exchange of their acids and bases?

In all these cases, the proportional numbers of the salts are themselves the answer to the question: consequently, as 67,705 nitric acid, with 35,600 lime, forms 103,305 nitrate of lime, and 27,655 carbonic acid with 58,990 potasse, forms 86,645 sub-carbonate of potasse; therefore 104 parts nitrate of lime, will require 87 of subcarbonate of potasse, to change them into nitrate of potasse, or saltpetre, and 127 parts of that salt will be produced by the union of the 68 parts of nitric acid with the 59 of potasse.

3. What quantity of zinc will precipitate the copper from 50 avoirdupois ounces of blue vitriol, or crystallized sulphate of the deutoxide of copper?

The number for blue vitriol is 203,355, which contains 56,215 of water, and only 149,140 of dry sulphate, composed of 50,000 dry sulphuric acid and 99,140 of deutoxide of copper, which, as it contains 20,000 of oxygen, will of course require two proportions, or 80,640 of zinc. Now, if 204 blue vitriol requires 81 of zinc, 50 ounces will require 19 to precipitate the copper.

4. How much oil of vitriol is required to expel all the nitric acid from one pound of saltpetre?

Saltpetre is composed of 67,705 nitric acid, and 58,990 of potasse, consequently its number is 126,695; now 58,990 of potasse, as it contains 10,000 of oxygen, is neutralized by 50,000 of dry sulphuric acid, or 61,243 of the hydrated acid, called oil of vitriol; therefore, 127 parts of saltpetre will require 62 of oil of vitriol, and, consequently, a pound will require very nearly half a pound of the oil of vitriol.

5. How much oil of vitriol and common salt is necessary to convert 20 avoirdupois pounds of quicksilver into corrosive sublimate, and what quantity of sublimate will they produce?

In this operation the quicksilver must be heated with the sulphuric acid to form sulphate of deutoxide of quicksilver, which will require four proportions of dry acid, namely, two to oxidate the quicksilver, by means of their own change into sulphurous acid, and two to unite with the deutoxide thus formed and neutralize it; by which there will be obtained a sulphate composed of 100,000 of dry sulphuric acid, and 273,160 of deutoxide of quicksilver.

As the deutoxide of quicksilver contains two proportions of oxygen, it will require two of common salt for its decomposition; now two of sodium are 58,180, and two of chlore are 88,026, forming 146,206 of common salt.

The 58,180 of sodium will absorb two proportions, or 20,000 of oxygen, and unite with two proportions, or 100,000 of dry

sulphuric acid, and thus form 178,180 of dry sulphate of soda. The 88,026 of chlore will combine with one proportion, or 253,160 of quicksilver, and form 341,186 of deutochlorure, or the corrosive sublimate of quicksilver.

If, therefore, 253 of quicksilver require four proportions, or 200 of dry sulphuric acid, which are equivalent to 245 of oil of vitriol, twenty av. pounds of quicksilver will require nineteen pounds .36 of that acid, the fraction being equal to rather more than five ounces and three-quarters.

Secondly, if 253 of quicksilver require 146 of common salt, twenty av. pounds will require 11.54, or rather more than eleven pounds and a half.

Lastly, if 253 of quicksilver produce 341 of corrosive sublimate, twenty av. pounds will produce 26.95, or nearly twenty-six pounds fifteen ounces and a quarter.

Dr. Wollaston has laid down the numbers of the most usual substances occurring in the practice of chemistry on a sliding scale of artificial numbers, by which persons versed in the use of a sliding rule may solve the problems of this kind that most frequently occur, by inspection: but this instrumental arithmetic only tends to prevent persons from acquiring a facility in calculation, and is, therefore, in the long run, a hindrance rather than a help.

The symbols used by the chemists to express the theoretical composition of bodies, being taken from their foreign Latin names, do not always accord with the English: an alphabetical list of them is here given, and to each of them is annexed Berzelius' and Thomson's proportional numbers.

| | | Berzelius. | Thomson. |
|---|---|---|---|
| A- | Acetic acid | 641,120 | 6,250 |
| Al | Aluminium | 312,330 | 1,250 |
| | Alumine | 642,330 | 2,250 |
| Aq | Water | 112,435 | 1,125 |
| Ag | Silver | 2,703,210 | 13,750 |
| As | Arsenic | 940,770 | 4,750 |
| | Arsenic acid | 1,440,770 | 7,750 |
| Au | Gold | 2,486,000 | 25,000 |
| Az | Azote | N· | 1,750 |
| Ba | Barium | 1,713,860 | 8,750 |
| | Barytes | 1,913,860 | 9,750 |
| B- | Benzoic acid | 1,509,550 | 15,000 |
| Be | Beryllium: or glucinium | 662,560 | 2,250 |
| | Berylla, or glucine | 962,560 | 3,250 |
| Bi | Bismuth | 1,773,800 | 9,000 |
| B | Bore or boron | 69,655 | 1,000 |
| Ca | Calcium | 512,060 | 2,500 |
| | Lime | 712,060 | 3,500 |
| C | Carbone | 75,330 | 750 |
| Ce | Cerium | 1,149,440 | 6,250 |
| Ch | Chrome | 703,640 | 3,500 |
| Cl | Chlorine | M:· | 4,500 |
| C- | Citric acid | 727,850 | 7,250 |

| | | Berzelius. | Thomson. |
|---|---|---|---|
| Co | Cobalt | 738,000 | 3,250 |
| Cu | Copper | 791,391 | 4,000 |
| Fe | Iron | 678,430 | 3,500 |
| Fl | Fluoricum | 75,030 | 2,250? |
| | Fluoric acid | 275,030 | 1,250? |
| F- | Formic acid | 463,930 | 4,625 |
| G- | Gallic acid | 791,780 | 7,750? |
| Hg | Quicksilver | 2,531,600 | 25,000 |
| H | Hydrogen | 6,217 | 125 |
| I | Iodicum | 1,266,700 | —— |
| | Iodine | I:· | 15,500 |
| Ir | Iridium | —— | 3,750 |
| K | Kalium, or potassium | 979,830 | 5,000 |
| | Kali, or potassium | 1,179,830 | 6,000 |
| L | Lithium | 255,630 | 1,250 |
| Mg | Magnesium | 316,720 | 1,500 |
| | Magnesia | 516,720 | 2,500 |
| Mn | Manganese | 711,570 | 3,500 |
| Mo | Molybdenum | 596,800 | 6,000 |
| M- | Mucic acid | 1,318,320 | —— |
| M | Muriaticum | 142,653 | —— |
| Na | Natrium, or sodium, | 581,840 | 3,000 |
| | Natrum, or soda | 781,840 | 4,000 |
| Ni | Nickel | 739,510 | 3,250 |
| N | Nitricum | 77,260 | —— |
| Os | Osmium | —— | —— |
| O- | Oxalic acid | 451,760 | 4,500 |
| O | Oxygen | 100,000 | 1,000 |
| Pa | Palladium | 1,407,500 | 7,000 |
| P | Phosphorus | 392,300 | 1,500 |
| Pt | Platinum | 1,215,230 | 12,000 |
| Pb | Lead | 2,589,000 | 13,000 |
| P- | Prussic acid | 339,560 | —— |
| R | Rhodium | 1,500,100 | 5,500 |
| Se | Selinium | 495,910 | 5,000 |
| Si | Silicon, or silicum | 296,420 | 1,000 |
| | Silica | 596,420 | 2,000 |
| Sn | Tin | 1,470,580 | 7,250 |
| Sb | Stibium, or antimony | 1,612,900 | 5,500 |
| Sr | Strontium | 1,094,600 | 5,500 |
| | Strontia | 1,294,600 | 5,600 |
| S- | Succinic acid | 627,850 | 6,250 |
| S | Sulphur | 201,160 | 2,000 |
| Ta | Tantalum, or columbium | 1,823,150 | 18,000 |
| T- | Tartaric acid | 834,490 | 8,250 |
| Te | Tellurium | 806,450 | 4,000 |
| Ti | Titanium | —— | 4,000 |
| U | Uranium | 3,146,860 | 26,000 |
| W | Wolframium, or tungsten | 1,207,690 | 15,750 |
| Y | Yttrium | 805,140 | 4,250 |
| Zn | Zink, or spelter | 806,450 | 4,250 |
| Zr | Zirconium | —— | 5,000 |
| | Zirconia | —— | 6,000 |

The numbers of Berzelius are to be considered as those actually given by experiment; those of Thomson as corrected numbers, formed by adding or rejecting small differences to make the numbers all multiples of the number of hydrogen, namely 125. The remaining differences between the two series arise either from Berzelius having expressed the number for oxygen which is the radix of the table, one hundred times larger than Dr. Thomson, or from

the latter having always considered the smallest proportion of oxygen found united with another element as a single proportion; whereas Berzelius attends to the properties of the mixed, and if it agrees with those that are known to contain two, three, or more proportions of oxygen, he estimates the proportion of the oxygen accordingly.

As oxygen very frequently unites, on the present system of numbers in the proportion of 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, 3, &c. to the other body considered as unity, Dr. Thomson is of opinion that the number taken as that of a single proportion of oxygen is, in fact, twice the real number, and that the usual series is 2, 3, 4, 5, 6, &c. proportions of oxygen, of which a single proportion never enters into combination, but always two at least.

## *Stahlian Theory.*

The proportional numbers remain the same on the Stahlian theory as in the Lavoisierian: only those attributed to hydrogen and oxygen are ascribed to water; and there is considerable reason to suppose that azote or nitrogen is also a very subtle and unweighable element, and that its weight, when separate, or combined with hydrogen and oxygen, is owing to the water combined with it.

The number for water taken from hydrogen gas, as the lightest compound of which it forms the ponderable basis, is 125; but when combined with other ponderable bases it always enters into composition in the proportion of nine charges, atoms or volumes, so that its number is 1,125, or its multiples in the same manner as oxygen, on Dr. Thomson's correction of the usual school hypothesis, generally combines on two proportions at least, or its multiples.

The following are the compounds of which water forms the ponderable base.

| | | |
|---|---|---|
| Hydrogen gas composed of . . . | 125 | Aq $H^x$ |
| Oxygen Gas . . . . | 1,000 | Aq $^{8}O^x$ |
| Azotic gas . . . . | 1,750 | Aq $^{14}N^x$ |
| Ammoniacal gas . . . . | 2,125 | Aq $^{17}N^x H^{3x}$ |
| Deutoxide of hydrogen . . | 2,125 | Aq $^{17}O^x$ |
| Nitrous oxide gas . . . | 2,750 | Aq $^{22}N^x O_x$ |
| Nitrous gas . . . . | 3,750 | Aq $^{30}N^x O^{2x}$ |
| Common air . . . . | 4,500 | 2 (Aq $^{14}N^x$)+Aq $^{8}O^x$ |
| Dry Nitric acid . . . . | 6,750 | Aq $^{54}N\,O^{5x}$ |
| Nitrate of ammonia . . . | 9,875 | Aq $^{54}N^x O^{5x}$+Aq $^{17}N^x H^{3x}$ |

The other numbers remain the same, but the generality of those bodies, esteemed as elementary, are considered as having dry hydrogen combined with them, except chlore and iodine, which must be considered on this theory as containing dry oxygen without water.

Organic substances are compounds of charcoal with water, and the three hypostatical principles.

It is probable that the three elements, hydrogen, oxygen, and nitrogen, existing in a free state, not only in the atmosphere but also in the regions beyond it, produce the phenomena ascribed to light, atmospheric electricity, magnetism of the globe, and the etherial medium. And, that, either free or in combination one with another, or with other elements of the same kind, they produce the phenomena of electrified bodies, galvanism, calorimotion and the like.

# AIRS.

## VENTILATION OF ROOMS.

A pure atmosphere is necessary to preserve health. There need not any attempt be made to prove it by reasoning; it is a truth universally known and acknowledged.

It has been said that the salubrity and healthy state of the air depend in a great measure on the quantity of oxygen gas it contains. Yet chemists have not been able to detect an appreciable difference between the air of an hospital and that of an open situation. Seguin tried the air of an hospital, the odour of which was disagreeable; but it gave him the same result as the external air. The researches of Priestley, De Mart, Gay Lussac, and others, all tend to establish the same result; which is, that the composition of the atmosphere is essentially the same every where, and that it is a true chemical compound.

If these experiments be correct, they prove that a deadly poison may be infused through the atmosphere, which the art of the chemist cannot detect; but of which we have better evidence than is given by the nicest tests of an analytical chemist, in the pale visages and weakly constitutions of the inhabitants of close and crowded cities; in the unhealthiness of particular districts, and in the important alteration which a change of residence often produces in individuals unaccustomed to such changes.

The atmosphere in the neighbourhood of the sea is said to contain muriatic acid, and no carbonic acid gas. If the presence of foreign ingredients in the atmosphere were attempted to be detected by accurate tests, it is probable that much important information might be obtained.

Men not only change the air by respiration, but discharge a considerable quantity of vapour from their lungs. The experiments on this subject afford results which differ considerably: the experiments of Dr. Hales make it nearly seven grains per minute; Dr. Thomson six grains; Dr. Murray and Mr. Abernethy three grains; Lavoisier and Seguin make it a little more than seven grains per minute. Six grains may be taken as an average result. It will not exceed this; because six grains would saturate eight hundred cubic inches of air at the temperature it is given out in respiration, and it will probably be seldom less.

The mixture of air, azote, carbonic acid gas, and vapour, at the temperature it is thrown off the lungs, being much lighter than common air at the same temperature, it rises with such velocity that it is entirely removed from us before it becomes diffused in the atmosphere.

It appears also that a man gives off, by insensible perspiration, about eighteen grains of vapour per minute; and it has been observed, that air which has been some time in contact with the skin, becomes chiefly carbonic acid gas.

It must, at least, be also desirable to change as much of the air of a room as the moisture given off would saturate in the same time; and, in a room at sixty degrees, on the supposition that, in consequence of the body being chiefly covered, the moisture given off does not, at the utmost, exceed eighteen grains; hence it will be necessary to change three cubic feet of air per minute for each individual that may be in the room: that is to say, as much of the air as the moisture given off would saturate.

And as warmth increases the exhalation of every species of noxious matter; hence, where a higher temperature than ordinary is necessary, a greater proportion of ventilation becomes essential. So that, upon the whole, there should be allowed a change of three cubic feet and a half in every minute for each person; and Mr. Tredgold is of opinion, that, considering the effects of the lamps or candles used for illuminating our apartments, a similar allowance of, at least, one cubic foot of air should be made for each of them.

The power of ventilation in a room should obviously be adapted to the greatest number of people it is supposed to contain at one time. It is obvious that we had better err in excess than defect.

The most difficult season for ventilation is the summer; when the difference of temperature will scarcely exceed ten degrees; hence the ventilation must be adapted to this slight difference of temperature.

Mr. Tredgold, from his theory respecting the draught of air through chimneys and ventilating pipes, is of opinion that if the cubic feet of air that will be vitiated every minute by the number of persons in the rooms, which he thus estimates at four cubic feet for each person, be divided by forty-three times the square root of the height that will be given to the ventilating pipes, the quotient will be the superficial feet that the area of the ventilating openings ought to measure.

This rule must be modified for churches and places of occasional resort, so as to answer to the time, and the number of persons who are to stay in them.

The openings for ventilation should be made in the ceiling, and may be concealed behind some ornament; those for supplying air should be nearly on a level with the floor.

With the means of letting out air at the ceiling, and of letting in a fresh supply at the floor, it is impossible that the ventilation can ever be imperfect, if it be contrived so that winds

may not cause an interruption. On the other hand, when ventilation is attempted by opposite apertures in the sides, it is in windy weather only that ventilation can proceed; and even then not with advantage, as will be evident from the principles established in the fourth chapter. There ought also to be the means of regulating the quantity of ventilation according to the season, by regulating the size of the opening. And it will, in all cases, be adviseable to make the openings for ventilation numerous and small, as this tends to equalize the draught, and prevents those currents of air which are prejudicial to health.

This mode of ventilating rooms, by pipes in the ceiling, cannot be used with open fire-places, unless the pipe from the ceiling is brought down to the fire-place, and there turned up so that the heat of the fire may cause a circulation of air to take place down the pipe into the chimney.

### *Ventilation of Rooms heated by Close Stoves.*

Count Rumford is by no means an advocate for the great ventilation usually thought necessary; he says, although in most of the rooms, in the north of Europe, which are heated by stoves, whose fire-places are not supplied with the air necessary for the combustion of the fuel from the room, the windows and doors are double, and both are closed in the most exact manner possible, by slips of paper pasted over the crevices, or by slips of list or fur; yet when these rooms are tolerably large, and when they are not much crowded by company, nor filled with a great many burning lamps or candles, the air in them is seldom so much injured as to become oppressive or unwholesome; and those who inhabit them show, by their ruddy countenances, as well as by every other sign of perfect health, that they suffer no inconvenience whatever from their closeness.

There is frequently, it is true, an oppressiveness in the air of the room heated by a German stove, of which those not much accustomed to being in these seldom fail to complain, and, indeed, with much reason. But this oppressiveness does not arise from the air of the room being injured by the respiration and perspiration of those who inhabit it. It arises from a very different cause; from a very common fault in the construction of German stoves in general. They are often made of iron; and some part of the stove, in contact with the air of the room, becomes so hot as to burn the dust which lights upon it, which never fails to produce a very disagreeable effect on the air of the room. Even when the stove is constructed of tiles or pottery ware, if any part of it in contact with the air of the room

is suffered to become very hot, which seldom fails to be the case in German stoves constructed on the common principles, nearly the same effects will be found to be produced on the air as when the stove is made of iron.

Though a room be closed in the most perfect manner possible, yet, as the quantity of air injured and rendered unfit for farther use by the respiration of two or three persons in a few hours is very small compared to the immense volume of air which a room of a moderate size contains, and as so much fresh air always enters the room, and so much warm air is driven out of it every time the door is opened, there is much less danger of the air of a room becoming unwholesome for want of ventilation, than has been generally imagined; particularly in cold weather, when all the different causes which conspire to change the air of warmed rooms act with increased power and effect.

Those who have any doubts respecting the very great change of air in ventilation which takes place each time the door of a warm room is opened in cold weather, need only set the door of such a room wide open for a moment, and hold two lighted candles in the door-way, one near the top of the door, and the other near the bottom of it. The violence with which the flame of that above will be driven outwards, and that below inwards, by the two strong currents of air, which, passing in opposite directions, rush in and out of the room at the same time, will be convinced that the change of air which actually takes place, must be very considerable indeed. These currents will be stronger, and, consequently, the change of air greater, in proportion as the difference is greater between the temperatures of the air within the room, and of that without.

People, in general, have great apprehensions of the bad consequences to health of living in rooms in which there is not a continual influx of cold air from without. But the currents of cold air which never fail to be produced in rooms heated by fire-places constructed upon the common principle—those partial heats on one side of the body, and cold blasts on the other, so often felt in English houses—are infinitely more detrimental to health than the supposed closeness of the air in a room warmed more equally, and by a smaller fire.

It has been already shown, that a person changes by respiration, in a day and night, somewhat less than nine pounds, out of the 109 pounds of air that an ordinary room contains, and allowing a night-light to change one-third of that proportion, then a couple of persons sleeping with a light, will only change in eight hours, about 90 cubic feet .02 or 6 avoirdupois pounds .780 of air, and render it unfit for farther respiration; so that but a small proportion only of the air will be rendered unfit for

respiration, in any moderate time, even if the room were closed in the most perfect manner.

Even in respect to the most thorough ventilation, the use of close stoves is advantageous; for rooms are made much more comfortable, and more salubrious, by close stoves; they may be more equally warmed, and more easily kept at any required temperature. All draughts of cold air from the doors and windows towards the fire-place, which are so fatal to delicate constitutions, are completely prevented. In consequence of the air being equally warm all over the room, or in all parts of it, it may be entirely changed with the greatest facility, and the room completely ventilated when this air is become unfit for respiration, merely by throwing open, for a moment, a door opening into some passage from whence fresh air may be had, and the upper part of a window; or by opening the upper part of one window, and the lower part of another. And as the operation of ventilating the room, even when it is done in the most complete manner, will never require the door and window to be open more than one minute, in this short time the wall of the room will not be sensibly cooled, and the fresh air which comes into the room, will, in a very few minutes, be so completely warmed by these walls, that the temperature of the room, though the air in it will be perfectly changed, will be brought to be very nearly the same as it was before the ventilation.

It would be quite impossible to ventilate a room heated by an open fire, in the complete and expeditious manner here described, as the air in a room is partially warmed, or hardly warmed at all, and the walls of the room, remote from the fire, are constantly cold; which must always be the case, where, in consequence of a strong current up the chimney, streams of cold air are continually coming in through all the crevices of the door and windows, and flowing into the fire-place.

### *Ventilation for Prisons, Ships, Hospitals, and Assembly Rooms.*

Sir George Onesiphorus Paul observes, that it is now about twenty years since the deleterious consequences of inattention to ventilation were set forth by Mr. Howard. So strong and so general was the conviction of the public mind, not only as to the evil pointed out, but as regards the remedies proposed by that indefatigable philanthropist, that the legislature thought fit to adopt the whole of his principles, and to make them the basis of several positive laws, under the direction of which the greater number of prisons of the kingdom have been re-constructed, and the remainder, with few exceptions, altered in conformity to the principle recommended by him, namely, that

of introducing currents of fresh air into, and through, every apartment.

In those prisons where attention is also paid to personal cleanliness, the gaol fever is unknown, unless brought into them by prisoners committed in a state of previous infection.

By equal exertion on the like principles, the healthiness of the ships of war has been so improved that they are no longer sources of this desolating pestilence.

Regarding hospitals, it cannot be proved that a relief so complete has been effected. Mr. Howard was not sparing in his strictures on the management of this important branch of our public institutions, but the improvement he suggested, went no farther than simply the introduction of fresh air. The reconciling this advantage with that generally diffused warmth necessary in sick rooms, seems to have escaped his contemplation, yet, considering the importance of pure air to patients, together with the no less important object of securing them from currents of cold air, it cannot be denied that much still remains to be effected.

Parish work-houses, school-rooms for both boys and girls, in every rank of life, manufactories, apartments for public lecturers, and ladies' assembly-rooms, these, together with the circumscribed cottages of the poor, remain in a state most dangerous to health, from imperfect ventilation. To these sources, and to no other, may be traced the few putrid and contagious diseases which occasionally show themselves amongst us, and which, to the credit of free ventilation, can no longer justly be called gaol or ship fever.

At a period of demonstrated success of the doctrines recommended by Mr. Howard, Count Rumford advanced opinions from which important effects have been produced.

In theory, this ingenious person has decidedly negatived the necessity, and questioned the propriety, of ventilation by the admission of currents of air, and in the construction of those buildings most immediately under his direction, he has certainly adopted a practice of a directly opposite tendency.

Opinions of such authority could not fail to be respected, and they must, at least, raise a doubt in the mind of the most confident advocate of an opposite theory.

The county gaol at Gloucester is constructed on Mr. Howard's principles, of admitting air to pass into and through it in two straight lines from one extremity to the other. There is no obstruction to a freedom of current, other than as the streams of air, passing through the long passages open at each end, move with the greater velocity, and of necessity carry with them the weaker currents passing out through the cells at right angles.

From the time this prison was opened in 1791, until the year 1800, about 1300 persons were committed to it, and, on the average, about 100 prisoners were constantly confined in it. In these nine years, the number of deaths were thirteen, and of these four sunk under the effects of disease brought into prison with them. During the year 1800, the prison was crowded in an uncommon and very improper degree, 214 having been confined, and the average number being 167, one prisoner only died, a woman aged sixty. At the opening of the Spring assizes, 1801, the time of the greatest numbers, there was not one prisoner sick, or in the hospital ward.

By this statement it appears that the proportion of deaths is so much below the common average in the ordinary situations of life, that the healthiness of this abode may be said to be peculiar, and it is in proof, that however currents of air may be found injurious to particular constitutions, they are not unfavourable to general health.

Every prisoner in this gaol, when not in the infirmary ward, sleeps in a room containing from fifty-two to fifty-seven feet of superficial space, built with bricks resting on an arch, and arched over so that no air can enter it but through the openings provided for it. As air is constantly passing immediately under and round it, on every side, it is necessarily dry, it is ventilated by opposite openings near the crown of the arch. To that opening which is towards the outward air, there is a shutter, which the occupant may close at will, but is so imperfectly fitted, that when closed, a considerable portion of air must enter by its sides. The opposite opening to the passage, the prisoner has no means of closing in any degree.

During the ten years these rooms have been inhabited, there have been three winters in which the cold has been intense. Yet, notwithstanding the querulous disposition of persons in their situation, a complaint has never been heard, from old or young, male or female, suffering by cold in the night apartments. Fahrenheit's thermometer has never been observed to be below 33 degrees, in the severest night, in the middle region of a cell in which a prisoner was sleeping; whereas, in the ordinary apartments of a dwelling-house, water is frequently known to freeze by a bed-side. And farther, it is the decided opinion of two able physicians, that no ill consequences have arisen from prisoners sleeping in the situation above described.

Hence, therefore, it is a fact established by experience, that in a room containing not more than from 415, or 439 cubic feet of air, in which there is no fire, the body of a person sleeping under a proper allowance of woollen bed-clothes, will so far warm the atmosphere around him, or, to speak more conformable to modern doctrine, so little of heat generated in the body

will be carried off by the surrounding air, that he will not suffer by a current passing at a distance over him, provided the apartment be secured from damp.

The day apartments are in like manner constructed with cross openings near the ceiling or crown of the arch, but there is also in each of them an open fire-place. Respecting these apartments it must be admitted that openings for free ventilation are incompatible with strong fires in open fire-places.

It is certain that in rooms so provided the danger arising from impure air is completely guarded against, yet this advantage is gained at the risk of another evil which, though not so important, should if possible be avoided.

The air which in the same room without an open fire-place would pass inwards by one opening and outwards by the other, being attracted by the fire to supply the constant rarefaction in the chimneys, passes inwards from both openings towards the fire-place, and the body of a person placed near it, being in its current, is exposed to the danger of partial chill. To this circumstance, in these apartments, I am inclined to attribute the few complaints of a dysenterical or aguish tendency which have occasionally interrupted the general health of this prison.

Besides, as the windows are generally closed in the night, although that is the most important time for ventilation, no other change of air takes place but what is effected by the open fires, which, whilst supplied immediately from the middle region, are constantly consuming the best air of the room.

As a remedy to these apparent defects in the ordinary mode of ventilation, Sir George imagined that, as the draft or determination of the air to funnels in the ceilings of the rooms requiring ventilation would be accelerated by the operation of fire, these channels or funnels, so provided, should be rendered air-tight, and brought to terminate immediately under the fire intended to work them. The ash-pit and fire-place should be so closed by doors as to prevent the fire from drawing the air from the room surrounding it: and then the whole draft or consumption occasioned by the fire must be supplied from the further termination of the ventilating channel or funnel.

This funnel may be applied according to circumstances, either to the ceiling of the room in which the fire is made, to the room below, or to that above it, and the draft thus produced may, by a proper apparatus, be increased or diminished at will.

By a fire made in a close stove, a ward beneath it containing about eighteen thousand cubical feet, filled with patients, and which in spite of all former means was ever remarkably offensive, was, in a few minutes, so relieved of contaminated air that the change was sensibly felt by all the patients in it without their perceiving any increased current.

The means of ventilation adopted in this hospital have been applied long ago by Mr. Sutton with perfect facility to ships.

If this stove or grate were properly fitted to this purpose over a lady's drawing-room, on the evening of assembly, it might be set in action, and the room beneath cleared of its impure air without recourse being had to opening of the windows; the openings in the ceiling might be rendered ornamental.

By applying the same principle to German or other closed stoves, the chief objection to their use in crowded rooms would be obviated, and where the indulgence of the habit of open fires was not in question, such stoves, if constructed of earthen materials, would afford a more genial warmth, and a due circulation be at the same time effected.

So fitted and constructed, they would be incontestably better than open fires for the wards of hospitals, poor-houses, manufactories, theatres for lectures, school-rooms, and prisons. Respecting the last-mentioned structures, Sir George observes, that if public kitchens with a sutler were appointed under due regulations, the present necessity for open fires for prisoners to cook individually for themselves would be superseded, much to their advantage.

On the other hand, it must also be observed, that if close stoves acting on this principle were adopted, Count Rumford's objections to the introduction of fresh air would be obviated with regard to any room in which they should be in action, provided the opening through which it entered was made on a level with the ceiling.

Air entering at this level would in the absence of open fires be acted upon by no other draft than the mouth of the funnel in the ceiling, and could not descend in currents to the lower region of the room.

In a room so filled with company as to vitiate the air within it, the atmospheric air entering being specifically heavier would indeed descend and be replaced by the ascending impure air, but as it would not descend by a stronger impulse than its difference of specific weight, it must be slow in its motion, and would produce no sensible current.

## SULPHURIC ACIDS.

There are two kinds of sulphuric acids manufactured, as they are used in many processes of the arts.

The first is that obtained by distillation from copperas, which was formerly the most usual process, and the acid was called the *vitriolic acid*, from the name, wiktril, given to copperas by the northern Europeans, and was distinguished into *spirit of*

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*vitriol*, or *oil of vitriol*, according to its degree of concentration.

The second species of sulphuric acid is that formerly obtained by burning sulphur under a glass bell moistened with water, and exposing the sulphurous acid thus obtained to the air until it was changed into sulphuric acid; hence the acid thus obtained was called *oil of sulphur by the bell*, and was sold at a much higher price than that from vitriol. This is now made much cheaper than the other, but as the artisans who formerly used oil, or spirit of vitriol, still ask for the acid by those names, this is sold under those titles.

### *Sulphuric Acid from Copperas.*

The sulphuric acid is produced in great quantities by means of fire, from the common copperas, merely by distillation without any addition. The green vitriol is made use of for this purpose, as it is to be met with at a low price; but Glauber preferred the white vitriol of Goslar, as yielding its acid with less force of fire.

In respect to the operation itself, the following particulars should be attended to:—First, the copperas must be calcined in an iron or earthen vessel till it appears of a yellowish-red colour; by this operation it will lose half its weight. This is done in order to deprive it of the greatest part of the water which it has attracted into its crystals during the crystallization, and which would otherwise in the ensuing distillation greatly weaken the acid. As soon as the calcination is finished, the vitriol is to be put immediately, while it is warm, into a coated earthen retort, which is to be filled two-thirds with it, so that the ingredients may have sufficient room upon being distended by the heat, and thus the bursting of the retort be prevented.

It will be most adviseable to have the retort immediately enclosed in brick-work in a reverberating furnace, and to stop up the neck till the distillation begins, in order to prevent the materials from attracting fresh humidity from the air. At the beginning of the distillation the retort must be opened, and a moderate fire is to be applied to it, in order to expel from the vitriol all that part of the phlegm which does not taste strongly of the acid, and which may be received in an open vessel placed under the retort. But as soon as there appear any acid drops a receiver is to be added, into which has been previously poured a quantity of the acidulous fluid, which has come over in the proportion of half a pound of it to twelve pounds of the calcined vitriol, when the receiver is to be secured with a proper luting.

The fire is now to be raised by little and little to the most

intense degree of heat, and the receiver carefully covered with wet cloths, and in winter time with snow or ice, as the acid rises in the form of a thick white vapour, which, towards the end of the operation, becomes hot, and heats the receiver to a great degree. The fire must be continued at this high pitch for several hours, till no more vapour issues from the retort, nor any drops are seen trickling down its sides.

In the case of a great quantity of vitriol being distilled, M. Bernard has observed it to contain emitting vapours in this manner for the space of ten days. When the vessels are quite cold, the receiver must be opened carefully, so that none of the luting may fall into it. After which, the fluid contained in it is to be poured into a bottle, and the air carefully excluded. The fluid that is thus obtained is the ordinary oil of vitriol, of which Bernard got sixty-four pounds from six hundred weight of vitriol; and, on the other hand, when no water had been previously poured into the receiver, fifty-two pounds only of a dry concrete acid.

Bleyl, a village in Bohemia, possesses among its other manufactures an establishment for the preparation of sulphuric acid. In that manufactory there are two sheds for the distillation of sulphuric acid. One has three galley-furnaces, each containing twenty nine retorts on each side; the other has but two galleys, each of which holds only twenty-one retorts on each side.

Each galley is a long square brick furnace, containing only a grate and an ash-pit, and is composed of two little walls of bricks, which at the top have their surface somewhat inclined inwards.

On each of its two sides is a sort of oven, of the same length as the furnace, and formed by means of a thin brick wall between them and the fire-place. These ovens are intended to dry the vitriol; and they are covered with flags of gneis, forming a kind of step or bank on which the receivers stand.

The calcination of the copperas to whiteness is performed in the ovens which have been already mentioned. The operation is easy. Nothing more is necessary than to put the vitriol into the ovens, and there stir it from time to time. The heat employed in the distillation drives off the water.

The distillation itself is performed in earthen retorts of the shape of a pear, each sixteen inches in length, with the necks but little bent, and having the mouth two and a-half inches in diameter. The receivers for the reception of the acid are also of a similar shape; they are fifteen inches long; their diameter is, at the mouth, an inch and a half, and at the bottom four inches.

The retorts are mounted or set in a galley in pairs, one on one side, the other on the other, and supported by placing the bottom of one against the bottom of the other; their mouths are disposed a little higher than their bottoms, in order that nothing but acid may pass into the receiver. The retorts are coated with luting before being placed in the furnace.

As soon as the galley is furnished with retorts, they are fixed to the walls of the furnace with pieces of brick, and a kneaded mixture of burnt and unburnt potters' earth. A layer of the same kneaded earth is next put upon their necks, and over this another layer of bricks, which fixes the retorts in a firm and solid manner.

When the retorts are thus mounted, long narrow bricks are placed on their ends, in a range the whole length of the furnace. This done, the whole is covered with large thick square bricks, which rest both on the bricks placed endways, and those above the necks of the retorts, which bricks are first coated with a layer of the kneaded earth. These large bricks are cut at the corner to give issue to the smoke. The smoke escapes also by a small chimney at the end of the galley, against the supporting wall.

Into each retort are put three pounds of copperas. When the retorts are filled, the fire is kindled in the furnace, and the phlegm is left to evaporate from the vitriol, which, even after its calcination, still contains a portion of water.

The next thing to be done is to fix the receivers to the retorts, the mouths of which they must enter. They are luted together at the junctions with potter's earth, pulverized and wrought into a paste with water and sulphuric acid. The same luting will also serve to coat the retorts. The hardened luting taken from the retorts and receivers, after the distillation is broken, and with the addition of a portion of fresh earth, wrought again into a soft paste, is applied in a subsequent distillation to the same use as before.

The distillation is commonly finished in the space of thirty-two hours. If the fire were removed sooner there would be a great loss of acid, which would still remain in the ill-burnt vitriol. The fire should be never excessively strong, but always equal till the last six hours, when it is made more intense, that it may expel from the vitriol the last portions of its acid. Each retort affords one pound and a half of oil of vitriol, or half the weight of the dried copperas.

When, after the strongest fire, the pots or receivers are observed to cool, the distillation is then known to be at an end, since the vapours have ceased to communicate heat to them. It is then time to extinguish the fire, and to leave the furnace to cool, that the pots may be removed from it. The furnace

should never be allowed to become quite cold before these be removed, otherwise the residues in the retorts will attract back a part of the acid.

In this manufactory the receivers are emptied only after every third distillation. This management is attended with two advantages; it is a saving of time, and it prevents that waste of the acid which takes place when the retorts are emptied after each distillation; and it causes the acid to be obtained in a more concentrated state; for, every time the receivers are emptied they must be supplied with a portion of water to condense the acid vapours; but when the same quantity of water is used for three distillations instead of one, the acid condensed in it must of course be stronger.

The retorts will serve for three distillations; and to empty them, after each distillation, they are not removed from their places; but the residuums are taken out by means of a small round iron rake, made with a handle of the same metal.

In order to know whether any of the retorts are cracked, they are sounded or struck with another small iron rod or rake; the sound indicates whether they are cracked or not. When any one is cracked, it is taken out, and another, prepared in the same manner as the rest, is put in its place.

### *Sulphuric Acid from Sulphur.*

This acid was formerly thought to be different from that obtained by distilling copperas; and as it was then made by a very troublesome process, it sold at ten pence the ounce, when the acid from copperas was three shillings the pound.

The original process was to put a crucible, filled with sulphur, under a glass bell, moistened on the inside, and by putting a piece of red hot iron on the sulphur to make it burn quick; the moisture of the bell absorbed the sulphurous acid, and this being exposed to the air was changed into the sulphuric, and being thus rendered less volatile, was concentrated by distillation, and thus the oil of sulphur by the bell was made. Moist close weather was chosen for this operation.

Homberg improved this operation so far as to make five ounces in twenty-four hours. He took the largest glass receivers he could procure, and finding the point opposite the centre of the neck by a plummet, he traced, with a writing diamond, a circle of ten inches in diameter, and then applying a red-hot iron ring of the same size to the trace, caused the circular piece to fall out. Under each of the receivers thus prepared, and slung over a pan of water, he put a large earthen pot, filled with ten or twelve pounds of sulphur in a melted state, keeping the vessel constantly full, changing it, if the

sulphur fixed, for another, and removing the crust by an iron wire.

The use of saltpetre in fire-works, causing sulphur and charcoal to burn without the presence of atmospheric air, suggested to Lemery and Lefevre its use to burn sulphur in close vessels. Dr. Ward, the celebrated nostrum-monger, first practised this at a manufactory at Twickenham, and afterwards at Richmond, near London. He used large glass receivers, and put a mixture of sulphur and saltpetre into an iron ladle, supported by a stone-ware pot in the receiver, which was stopped with wooden bungs.

The receivers were placed on their sides, on a sand-bath, gently heated, and had a little water put into them, the vapour of which absorbed the acid: by this means he reduced the price to 2s. 6d. the pound, selling it under the name of oil of vitriol made by the bell.

The use of glass receivers being expensive and inconvenient, Dr. Roebuck began at Birmingham, in 1746, the practice of burning the sulphur, and receiving the product in leaden chambers, or houses, as they are technically called. Since that time, manufactories of sulphuric acid on this principle, have been established, on an extensive scale, in several parts of the kingdom; and the price has been still farther reduced.

It has not yet been settled what dimensions are the best for the leaden chambers. The manufacturers construct them according to their convenience; and Parkes, in his Essays, mentions a manufacturer in Lancashire, who built several rooms 120 by 40 feet, and 20 feet high. [The most modern English chambers are from 12 to 15 feet high, 15 to 20 feet wide, and 80 to 100 feet long; but the exact form or size, seems to have been in every case determined rather by the fancy or whim of the manufacturer, than by any knowledge deduced from actual experiments.] Whatever may be the size of the chambers, the process has been usually conducted in the following manner.

Common brimstone, coarsely ground, is mixed with saltpetre in the proportion of eight pounds of the former to one of the latter; and the mixture is spread on leaden or iron plates, placed one on the other, at a little distance, the upper plate being empty, and on stands of lead within a chamber wholly lined with lead, and covered at the bottom with a thin sheet of water. About one pound of the mixture is allowed to every three hundred cubical feet of atmospheric air contained in each chamber; and when a charge in this proportion has been placed in one of them, the mixture is lighted by means of a hot iron, and the door is closed.

The combustion of the two substances, if well mixed, continues about forty minutes. In about three hours the gas is all

condensed, and the chamber is thrown open, for a quarter or half an hour, to admit atmospheric air, and prepare it for another burning. The plates are again charged, and the same process is repeated every four hours, without intermission, either by day or night, until the water at the bottom of the chamber is thought to be sufficiently acidified. This is judged of by the acid turning black, when it is drawn off by means of a syphon, into a leaden cistern.*

The acid, which has then the specific gravity of about 1.450, is concentrated by the action of heat in leaden kettles, until it has acquired such a specific gravity as best suits the manufacturer's purpose. It is afterwards boiled in very large glass retorts, set in sand-pots, till all the sulphurous and nitric acids are driven off, and it is fit for the market. Of late years these retorts have had coils of platinum wire, or strips of platinum foil put in them, to equalize the boil, and prevent those concussions which were apt to crack the retorts. The necessity for the concentration by means of heat, arises from the water, after it has taken up a certain quantity, refusing to absorb the acid so readily as at first. Care too must be taken, when the acid is in the leaden boiler, that it be not too much concentrated, for the boiling point of concentrated acid, and the melting point of lead, are so near to each other, that the leaden boiler may be destroyed.

Some manufacturers remove it at once into the glass retorts, and do not steam it in lead, which prevents the acid combining with so large a quantity of this metal. The acid is usually left in the retorts for twenty-four hours, when the retorts are either hoisted out of the sand, and the acid poured into carboys, or the acid is drawn off by a syphon, without moving them.

Lately, platinum bodies, placed within pots of cast-iron, of a corresponding shape and capacity, have been substituted for the glass retorts, and have been found to save fuel, and quicken the process of concentration. Parkes mentions that he had a platinum still constructed for rectifying sulphuric acid some years ago: it cost him three hundred pounds, but answered the purpose perfectly well.

The oil of vitriol thus prepared, always contains sulphate of potash, derived from the nitre, and sulphate of lead, derived from the leaden vessels used in the process.

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* This is a very uncertain criterion for judging of the strength of the acid in the chamber, as it depends not merely on the state of the concentration of the acid, but on the cleanliness of the chamber or freedom from vegetable matters which are charred by the acid when it acquires a certain specific gravity. Other things equal the amount of discoloration will be determined by the quantity of these impurities.—Am. Ed.

In order that this method should succeed, it is essential that air be present to maintain the combustion, that the closed chamber do not allow the volatile matter which arises to escape, and that water be present to absorb it. For a long time, however, the theory of this method was involved in doubt and obscurity.

It was found that one hundred parts of nitre, containing only thirty-nine and a half of oxygen, when combined with the requisite quantity of sulphur, produced a quantity of sulphuric acid, containing twelve hundred parts of oxygen. Besides, after the combustion of the sulphur, the residuary salts contain nearly as much oxygen as was originally contained in the nitre; and twelve hundred parts of oxygen in the acid could not be accounted for.

Pluvinet first attempted to explain this circumstance, in a letter to the elder Chaptal, and since then, Messrs. Clement and Desormes, two French manufacturing chemists, have revived, after a lapse of some years, this theory, and their explanation has since been received as true, by Mr. Dalton and Sir H. Davy. It is now supposed, that the burning sulphur, taking from the nitre a portion of its oxygen, forms sulphuric acid, which, uniting with the base of the nitre, or potasse, displaces nitric and nitrous acids in vapour, which is decomposed by the sulphurous gas, into nitrous gas, or deutoxide of azote. Being naturally only a little heavier than air, and being then rarefied by the heat, the nitrous gas rises to the roof of the chamber, and there coming into contact with atmospheric air, by means of a hole left there for that purpose, and without which, as they affirm, the manufacturers found that the acidification would not go on, forms nitrous acid vapour, which being a heavy body, immediately precipitates on the sulphurous flames. Sulphuric acid and nitrous gas are again formed, and the latter again mounts for a new charge of oxygen, again to re-descend and transfer it to the sulphur.

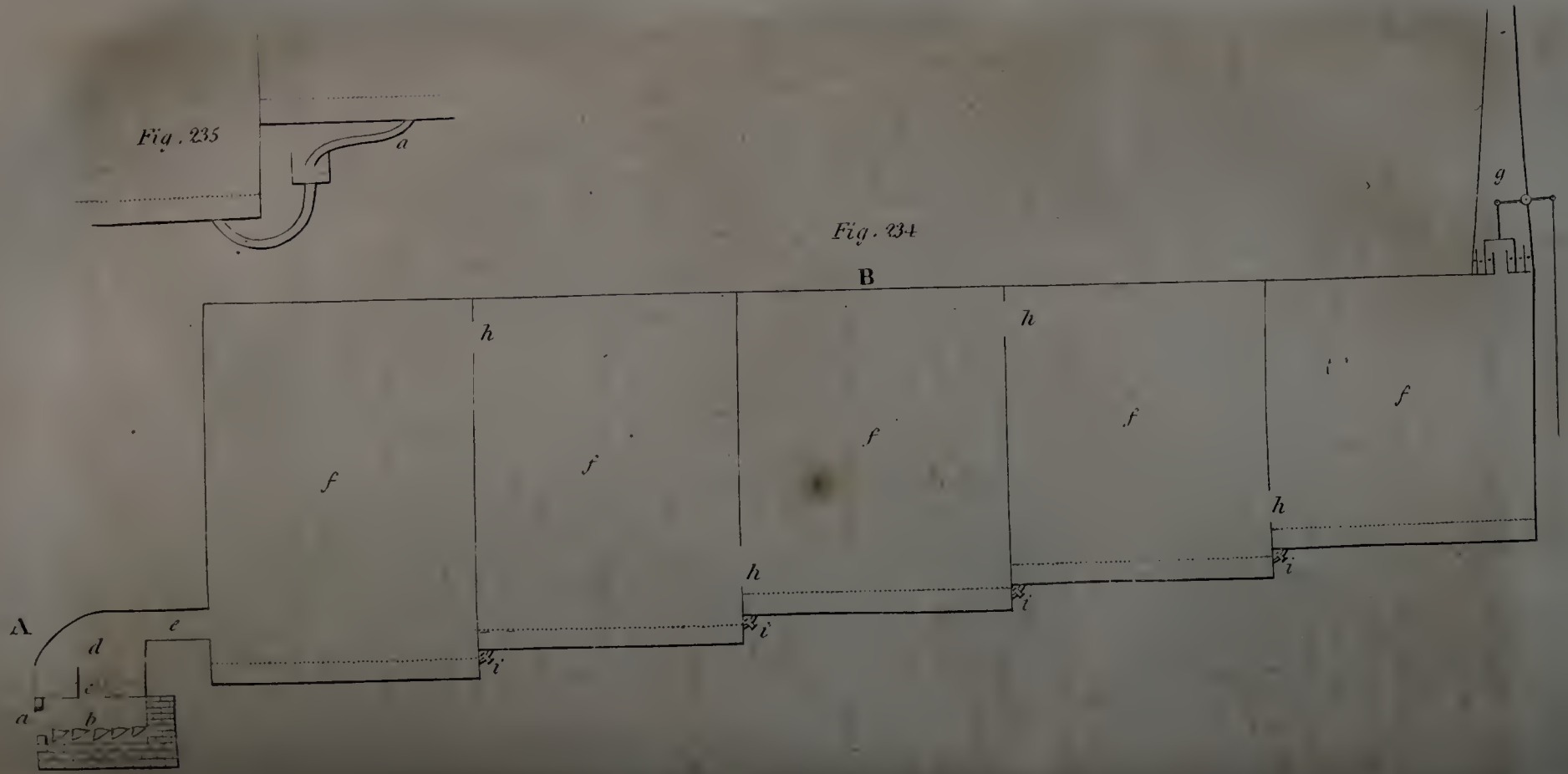
Sir H. Davy has, however, since shown, that water is necessary to the mutual action of sulphurous gas and nitrous gas, and unless this fluid is present the process does not go on. With this additional fact it would appear, that a small volume of nitrous acid vapour, by its alternate and frequent changes into oxide and acid, is capable of acidifying a great quantity of sulphur.

A manufacturer of this acid remarks, in the "Chemist," that the method described by Parkes has been abandoned by the English makers. It proves, however, though Messrs. Clement and Desormes affirm the contrary, that the acidification will go on without any hole, for the admission of atmospheric air, in the roof of the chamber. In the old method of opera-

Fig. 235




Fig. 234



ting, the first charge, by being burnt, would form some portion of incondensible gas; this, by the admission of atmospheric air at the doors, was driven to the top, and thus each charge lessened the capacity of the chamber, until, after a week's work, the sulphur would scarcely inflame. On a moderate computation, not one half of the sulphur was really used. The maker, of course, could never have made sulphuric acid by this method, at the price it was usually sold at, but that the unconsumed sulphur, mixed with the sulphate of potash, was sold to the maker of roll sulphur, at a price nearly that of duty-paid sulphur, nine-tenths of which duty the sulphuric acid maker had returned to him, by his disregarding his oath, that the said sulphur was all consumed by him, in the making of oil of vitriol.

[The foregoing is a correct description of the method of conducting this branch of manufacture still practised in many of the old works in England, and almost universally in those of the United States. In recently constructed works, the process is conducted on a much improved plan; that of keeping up a constant combustion and circulation through the chamber from the commencement to the end of the process. Fig. 234, will serve to illustrate this plan, though the division of the leaden chamber, *b*, into compartments at different elevations from the earth, relates to another plan engrafted upon this, to be afterwards described. For the present, we will consider the chamber, *b*, as a plain one on the ordinary construction. *A*, is the fire-place in which the sulphur and nitre is burned, surmounted by a small leaden apparatus containing water, which is boiled by the heat produced by the combustion of the sulphur: *b* is the fire-place which is built of brick; *a* the door leading to the fire-place; *d* the leaden vessel placed directly over the fire-place, the bottom of which is covered with water to the dotted line; *c* a circular opening six inches in diameter, through which the sulphurous vapour ascends from the burning sulphur; and *e* the passage leading into the chamber: at the opposite extremity of the chamber is a wooden chimney, or flue, *g*, for the escape of the incondensible vapour of the chamber, which is ordinarily kept open, but which may be closed or lessened at pleasure, if the escape of sulphurous acid is apprehended, by the common water trap or water valve.

Now, the operation of this apparatus is this:—the sulphurous and nitrous gases produced by the combustion of the materials in the fire-place, *b*, ascend through the tubular aperture, *c*, into the small chamber, *d*, where they meet and mix with a portion of watery vapour, which arises from the water in this vessel (which is kept in a state of gentle ebullition by the combustion of the sulphur underneath) and pass together into the chamber, *B*, where the changes already described agreeably to the views

of Messrs. Clement and Desormes and Sir H. Davy take place; a portion of undecomposed air, also passes into the chamber to supply the waste of oxygen, and the incondensible nitrogen, and perhaps small portions of other gases, pass off through the chimney, *g;* in consequence of this constant change in the aerial contents of the chamber, the process may be carried on without a moment's interruption till the water in the chamber is impregnated to the required point.

The theory of Messrs. Clement and Desormes does not essentially rest, as the author and others would seem to infer, on the question whether this process can be profitably carried on with or without an opening in the top of the chamber where all other openings are closed. It is certain that the combustion of the sulphur with the nitre may be effected to a certain extent without any opening at the top of the chamber, or in any part of the chamber, but it is equally certain that it may be supported a much longer time where there is an opening for the admission of air. If the combustion be attempted in a chamber completely enclosed, it is limited by the absorption of the oxygen of its own atmosphere; if in a chamber with a small opening at top only for the admission of air, it is limited and interrupted in a short time by the accumulation of incondensible gases, which occupy the whole of the chamber, and in that way prevent the admission of oxygen. Hence the necessity on the old plan of making oil of vitriol, of so often stopping the process of combustion, and throwing open the chamber for a thorough ventilation, or sweetening, as the workmen called it. It would seem a little remarkable that these accurate observers had not been conducted by their researches on this subject to one of the most signal improvements in this branch of manufacture. They seem to have been so much occupied with the beautiful play of chemical attractions between the gaseous products of the combustion and the oxygen of the atmosphere as to have overlooked the necessity of vent for the incondensible nitrogen. The admission of air through the top of the chamber only, does not necessarily follow from the theory of these gentlemen; but they probably apprehended, as many practical oil of vitriol-makers of the old school still do, that, if a vent were also made at the fire-place, and a current established in the chamber, there must be great danger of loss of considerable portions of the sulphurous and nitrous gases at the upper aperture. But the most ample experience has demonstrated that no such loss need be feared where the process is conducted with ordinary caution. So far is this from being the case, that the writer recollects visiting a very large establishment in Ireland, conducted on the principle of a constant combustion, in which several chambers were completely enclosed, and covered by a large building, with a tight roof, into which the incondensible

gases were suffered to escape without any other ventilation of the building than the ordinary doors; and yet the atmosphere was far less offensive from sulphurous fumes than such buildings usually are with chambers constructed on the old plan.

When the water in the leaden vessel *d*, becomes saturated with sulphuric acid, it may be drawn off and its place supplied by a fresh portion: it will, indeed, be necessary to introduce fresh water frequently, to supply the waste from evaporation; but it will seldom be required to draw off the liquid, as the absorption of acid will be very slow at the boiling temperature of the water. It would be well to insert one or two gauge cocks; similar to those used in steam boilers, only of lead, into this small chamber, to enable the workmen to regulate the admission of water; or what would be equally simple, and, on the whole, preferable, a glass tube half inch in diameter, twice bent at right angles, one end of which should enter above, and the other below the water line, by which the attendant could at all times know the exact amount of water within.

In order to moderate the combustion, it is now, I believe, the invariable practice of oil of vitriol manufacturers to mix the sulphur and nitre with pipe clay; for this purpose, for every 100 pounds of brimstone, they take fourteen pounds of pipe clay, and fourteen pounds of crude nitre; the latter is dissolved in as little water as possible, and then added to the clay and sulphur, which are previously pulverised, and the whole beat into a stiff paste; this paste is then moulded into lumps of a conical form of twenty pounds each, and when nearly dry, they are placed in two or three rows in the furnace, with the apex of one touching the base of the other; the object of this particular form and arrangement of the lumps is to secure the combustion of the lumps in succession; as they touch only by a small surface, the combustion of the first in order is nearly completed before the following one is kindled. It is usual to mix the materials the day before their use; the lumps should be damp, but not wet. The proper degree of moisture will, however, be soon learned by trial. The lumps retain their form after the combustion has ceased, and will be found to consist of sulphate of potash and sulphate of alumine, with a considerable excess of base. They are used in the manufacture of alum.

With regard to the density of the liquor when drawn from the chamber, that will depend much upon the choice of the operator; at least the writer is not aware of any accurate experiments having been instituted to determine the most economical points at which to stop the process. Some manufacturers draw off the acid at a specific gravity of 1.250, and others not till it reaches as high as 1.500. The nearer the liquor approaches the saturated point, the slower will be the absorption; but, on the other

hand, the denser it is when drawn from the chamber, the less fuel and time will be required for its subsequent concentration. The practice of the manufacturer may, therefore, be modified by circumstances to a considerable extent; if his fuel is cheap, and his chambers limited, it will be adviseable to draw off the acid from the chamber at a low specific gravity; on the contrary, if fuel be dear, and his capital for investment in chambers ample, it may be profitable to carry the concentration in the chamber much higher.

Theoretically one hundred pounds of sulphur with the above quantity of nitre should yield three hundred and twelve pounds of concentrated sulphuric acid; but two hundred and eighty pounds is accounted a good product in practice. It is not contended that the yield of acid is greater in the new plan of operating by a constant combustion; but only that there is a great saving of labour and time in conducting the process, and that more acid is produced from a chamber of a given capacity,—considerations of no ordinary weight in a branch of manufacture requiring under the most favourable circumstances so heavy an outlay of capital as this.]

In the present plan pursued by the English manufacturers, the sulphur and saltpetre are in different vessels, and both are in furnaces separate from the chamber, and several feet distant; consequently, all the advantages of the new French method, hereafter described, are obtained with this additional one, that sixteen charges can be burned in twenty-four hours.*

It has long been an object with the manufacturers to procure sulphuric acid without the assistance of saltpetre; and this has been performed in England by Messrs. Hill and Huddock, who have taken out a patent for this purpose. They subject pyrites, or sulphuret of iron, in a state of powder, to a strong red heat, in cast-iron cylinders, communicating with a chamber lined with lead containing water, into which, they say, they inject steam and a certain imponderable substance. As this substance is not mentioned; their patent is, of course, of no force. It seems probable that they use common manganese, or the black oxide of that metal, instead of saltpetre, either mixed with the pyrites, or in a separate cast-iron cylinder.

It is found that the sulphur evolved by this means, and burning, produces sulphuric acid, which is immediately condensed in the water. The great advantages of this method are, that

* What is intended here by putting the nitre and sulphur in separate vessels it is difficult to conceive; certainly no manufacturer ever thought of burning the nitre and sulphur in separate vessels: crude notions of this description in relation to the chemical arts not unfrequently find their way into our scientific periodicals and thence into our best systematic works through inadvertence.—Am. Ed.

no saltpetre is necessary, and pyrites, a material which was before hardly put to any use, but that of making copperas, is the material employed for furnishing the acid.*

The improvements in the manufacture have been so great in England, that a pound of acid, which twenty years ago cost sevenpence, may now be had at the wholesale price for less than twopence.

The quantity consumed in Great Britain is about three thousand tons a year.

### *French Manufacture of Oil of Vitriol.*

The principles of the French method of manufacturing this acid were the same as those of the method followed in England; but the details very different. Mons. Payen informs us that sulphuric acid was manufactured in France, forty years ago, by burning sulphur with saltpetre, but at present, by reverting to the old process of burning sulphur alone.

The process with saltpetre consisted in shoving into a chamber lined with lead, containing from five to ten thousand cubic feet, an iron carriage, carrying a cast-iron dish full of burning sulphur, the combustion of which was promoted by a portion of saltpetre, amounting to ten, fifteen, or even twenty in the hundred. Some manufacturers injected a shower of water by a forcing pump, through a rose. When it was supposed that the combustion was completed, and that the acid formed had been condensed by the water, the door was opened at which the chariot had been introduced, it was taken out to clear away the residuum, again loaded, and the operation repeated.

The acid obtained was evaporated and concentrated in leaden boilers 50° to Baumé, and then concentrated in glass retorts, ranged, as many as twenty or thirty, in a sand bath, and all heated by the same fire.

The result of all these proceedings was to obtain from 150 to 200 parts of sulphuric acid, of the specific gravity of 1,845, or 66° of Baumé for every hundred of sulphur employed, and very often the operation entirely failed. The residuum was at first flung away, although it contained nearly one-third of the sulphur used, and much sulphate of potasse; but afterwards it was sold to the alum-works, and used in that manufactory.

The putting in the sulphur by a carriage was then done away, and an immoveable furnace constructed under the chamber.

* The writer was informed, when in England in 1827, that the plan of Messrs. Hill and Huddock had not answered the expectations first formed of it, and that the manufacture on these principles had been abandoned. A similar attempt to manufacture this acid from pyrites was made a few years since, by a manufacturer in Manchester, but did not succeed well. The ruins of an expensive apparatus remain to attest both the enterprise and misfortunes of the projector. Am. Ed.

The dish in which the sulphur was burnt was heated by fire, and the mixture of one hundred parts sulphur to ten or twelve saltpetre was introduced from time to time, by means of a small door for this purpose. A hole, two inches above the level of the sulphur, permitted a constant ingress of air, and a chimney at the other extremity created a draught which carried off the uncondensed gases. In damp weather, particularly, they fell all around, and destroyed all vegetation in a pretty extensive circle.

Some acid was always left in the chamber; and as more was formed, a quantity was drawn off and concentrated in glass vessels. This method of concentrating the acid is still generally employed, except that, instead of several glass retorts, a single platinum alembic is now in use. By this process from 250 to 260 pounds of acid, of the specific gravity of 1·845, are obtained from one hundred pounds of sulphur.

The following method, which is practised by some manufacturers, is said to give constantly three hundred pounds of acid of the specific gravity of 1·845 for every one hundred pounds of sulphur. According to the theoretical calculation of the proportional charges of sulphur 100, oxygen 150, water 62·50, the sum would be 312·50, and it is scarcely possible to come nearer on a large scale.

According to this new method, the best size for the chambers is thought to be about fifty feet in length, twenty-seven in breadth, and fifteen in height, or rooms containing about twenty thousand cubic feet; chambers of different dimensions may be used; but this is the size to which the manufacturers give the preference.

Fig. 103, represents a chamber of this kind. A leaden cylinder, *b*, eight feet in diameter and six feet in height, enters the chamber at one end, and rises about ten inches above the floor, *c*. The cylinder at its lower part, *d*, turns inwards and upwards, and forms a gutter, *e*, concentric to the cylinder, in which there is a constant quantity of acid kept as high as *g*, to prevent the lead from getting too much heated, and to profit by the heat of the acid which continually passes. The whole is placed on a mass of brick-work, *h*; in the middle of which there is an iron dish, *k*, three feet four inches in diameter, and one inch thick, slightly concave, and having a rim three inches high. This is set above the fire, *b*, which ought to heat all its under surface. Level with the rims, a door, *m*, is made into the leaden cylinder, two feet high, eighteen inches wide, and having at its lower part a hole, *n*, an inch in diameter.

At the other end of the chamber are two ventilating valves, *p*, and two wooden pipes, *q*, sufficiently high to promote a strong draught.

Every thing being ready, the door and the valves closed, and the bottom of the chamber covered with diluted sulphuric acid, at 10 or 15° of Baumé, the fire is lighted under the iron dish, and when it is so hot that a handful of sulphur thrown on it instantly takes fire, it is charged with sulphur, of which it takes fifty kilogrammes, about 115 pounds, for every operation.

At the same time, a retort containing nine pounds three-quar-

ters of nitric acid, and one pound four ounces of molasses, is heated. The nitrous gas disengaged in this process is conducted by a pipe into the leaden cylinder, two fect above the burning sulphur, and this operation is continued till all the nitrous gas is disengaged. What remains in the retort after this operation is crystallized, and makes oxalic acid, so that the nitrous gas is thus procured without any expense, as a secondary product, and the expense of saltpetre totally avoided.

About two hours after beginning to burn the sulphur, the cock of a boiler, *s*, is opened, the steam-pipe of which, *t*, enters the middle of the chamber. Its diameter is one inch, which, at its mouth, is reduced to half an inch, in order that the vapour, arising from the boiling water in *s*, may issue with some force. This cock is to be kept open till all the vapour necessary for the absorption of the acid, which is about the produce of fourteen gallons of water, has been thrown into the chamber. Soon after the introduction of the vapour a condensation in the interior is perceptible, and the hole, *n*, is opened in order to give access to the atmospheric air.

In general, the injection of vapour is stopped about an hour after the combustion of the sulphur; and when this is done, and it is supposed that the condensation is complete, the door of the cylinder, and the two valves for ventilation, are opened, in order to renew the air of the chamber, and another operation is then begun. This may be repeated four times in twenty-four hours; but it is difficult to keep up this constant work. It is better to perform only three, and even as two require less close inspection, and the apparatus is less liable to accidents; and more produce in proportion being obtained, it is, perhaps, on the whole, better to work it only twice in the twenty-four hours, namely, in the day time. The metal suffers considerably less from its alternate expansion and contracting under this mode of operating.

The bottom of the chamber should always be covered with liquid; and as it is laid inclined to the horizon, the liquid is nearly nine inches deep at one end, and only one inch and a half at the other; the overplus only of acid should be drawn off daily. The concentration can be carried on in the chamber to a considerable extent, even to 50° or more of Baumé; but then the acid absorbs a portion of the nitrous gas, from which it is scarcely possible afterwards to free it. In consequence of the water necessary for the acid being furnished from vapour, and thus being, in fact, distilled water, the acid obtained is not contaminated with the sulphate of lime, usually contained in common water, and it dissolves indigo without injuring its beautiful blue colour.

If it is ever found necessary to draw off the whole of the acid from the chamber, for making repairs, or from any other cause, care must be taken to cover the bottom of the chamber, before beginning anew, with weak acid. Some manufacturers, who have neglected this precaution, and put either plain water,

or nothing into the chamber, have obtained no product. Heat and water are essential to the formation of the acid; and it has been observed, when working four times in the twenty-four hours, or constantly, that in dry weather, particularly if frosty, the acid was never condensed. As the cause of this circumstance was not known, it was attributed to the chambers, which were said to be sick, and would not work. The remedy was to throw steam into the chamber, and thus heat the sides. The same precaution must be taken, if the chamber is begun to be used in dry or cold weather.

The acid thus obtained is first boiled down in shallow leaden pans, about a foot deep, in which it is brought to fifty degrees of Baumé. After this it is distilled in a platinum still, having a moor's head of the same metal, and a leaden adapter. The water which comes over brings with it some acid, and hence may be advantageously used in addition to the liquid in the chamber.

The concentrated acid is drawn out of the platinum body by the help of a platinum cane, which is surrounded by a copper pipe, through which a current of cold water is made to run, in order to cool the acid, and prevent it from cracking the stone-ware cisterns in which it is first kept by the manufacturers. From these cisterns it is drawn off into stone-ware bottles, with stoppers of the same material, luted over with clay.

No accurate estimate of the quantity of acid obtained in England from the combustion of sulphur has been published, to enable us to compare accurately the vlaue of the two methods. If, however, the French statement we have given is correct, we should suppose the latter the most profitable, as the expense of the saltpetre is entirely avoided, there being a sufficient demand for the oxalic acid.

The only drawback seems to be the recommendation not to repeat the operation more than three times in the twenty-four hours, while, by the English method, the work is constantly going on. This is a point of great importance in consequence of the large capital embarked in such manufactories; but it must, at the same time, be remarked, that there is no reason why the English method should not cause as much injury to the buildings and machinery as the French.

Independent of this, the latter seems to have considerable advantages. The substituting a plate of sulphur, exposed to exterior heat, and the mixing the nitrous gas with the flame of the sulphur, instead of mixing the two raw materials together, and the method of throwing in steam to supply both heat and pure water, must unquestionably produce a greater quantity of acid than is obtained by the English method, and of a purer nature. Whether this advantage is sufficiently great to counterbalance

the expense of the fuel consumed, we have no means of determining, but we have the testimony of the French manufacturer in its favour.

[There is reason for believing that no extensive work for the manufacture of oil of vitriol has ever been conducted on the principle described in the foregoing paragraphs, not even in France. The writer visited several establishments of this kind in Paris and Rouen, in 1826. They were all conducted on the old English plan of close combustion of nitre and sulphur, with the modern improvement only of a separate chamber for the combustion; but in this part of the process, the materials were kindled on the old plan of a separate fire underneath a large iron basin, in which the sulphur and nitre were placed. In one instance only, did he witness the arrangement for injecting steam into a chamber, in the manner described by the author, and in that case the boiler had evidently not been used for a length of time, although the chamber was in constant operation; he either did not inquire, or does not now recollect, the reason assigned by the manufacturer (M. Chorrillon) for the disuse of this apparatus. An English chemical manufacturer of great experience, combined with much scientific knowledge, informed the writer that he once came very near paying dearly for this suggestion of a theoretical chemist, in the destruction of his chamber: notwithstanding the valves provided to open both inwards and outwards, he found the contractions and expansions of the aerial contents of the chamber so sudden and violent, as to render it impossible to proceed with the process. Another experienced manufacturer informed him, that he tried the effect of steam in a small chamber, erected for this purpose, and could form no vitriol whatever. The advantage of steam in any considerable quantity is indeed very problematical, in this process, independent of the mechanical objections to its use. With regard to the use of nitrous gas, from the action of nitric acid on molasses, instead of nitre as mentioned by the author, there seems no objection to the measure in theory; but it probably remains to be demonstrated how far it is practicable, and profitable on a large scale. The account given of this method of manufacture is the substance of an article in the Dictionnaire Technologique, which has never been much esteemed by practical manufacturers.

### *Dr. Hempel's Oil of Vitriol Chamber.*

Various attempts have been made to increase the absorption of the sulphurous vapour, by dividing and subdividing the interior of the leaden chamber, or with the view either of bringing the sulphurous acid more frequently in contact with the water of the chamber, or of presenting to it different portions of water, in different states of saturation. One of the most systematic arrange-

ments of this kind, is that of Dr. Hempel, a celebrated chemical manufacturer of oil of vitriol, and other chemical articles, of Berlin, the particulars of which were given me by an English chemist. Fig. 234, exhibits a vertical section of Dr. Hempel's chamber. It is 100 feet long, 17 feet wide, and divided into five different compartments by transverse partitions. The deepest of these compartments is 15 feet, which is that nearest to the furnace in which the sulphur is burned; each succeeding one is one foot less in depth, and, consequently, the last is only 10 feet high. The position and depth of the water in these compartments is represented by the dotted lines. *i i i i* Represent tubes and stopcocks which must be of lead or glass, through which the liquor may be drawn at pleasure from the higher chambers to the lower. The first partition is pierced near the top of the chamber by a row of circular apertures, near the top of the chamber, and extending from one side of the chamber to the other. The second is pierced with a similar row of apertures near the surface of the fluid, in the third compartment: the third partition is pierced like the first at the top, and the fourth, like the second at the bottom. In the sketch the position of these apertures are represented as though the partition were actually terminated, or cut off in that line. The sulphurous and nitrous fumes enter the first compartment through the pipe, *e*, along with a portion of air; the ordinary changes here take place, and a portion of sulphuric acid is formed, and absorbed by the water of this compartment, the remaining gases then rise, pass through the apertures at *h*, (which may be 10 in number, of two to three inches in diameter,) into the second compartment, where the same changes as in the first occur, and so on through the remaining three, the current setting through them in the direction and course of *h h h h* and finally out at the chimney, *g*, in which the water valve at the base should have been represented open. By this arrangement, an active circulation and mixture of the aerial contents of the chamber are secured, and the gases either at their entrance, or escape from one apartment to another, are made to sweep over, and in immediate contact with the surface of the water.

It is obvious from the sketch, that the water in the first compartment will be soonest saturated, because there the sulphurous and nitrous vapours will exist in the greatest degree of concentration, and so on each chamber successively will be weaker and weaker to the last. When, therefore, the water in the first compartment is saturated to the required point, it is drawn off; (for which purpose it is convenient to have the leaden chambers elevated above the leaden evaporating pans:) there the liquid in the second compartment is drawn into the first, that of the third into the second, and so on till the last compartment is empty,

which is then replenished with fresh water, and the process of combustion again renewed and continued till the water in the first compartment has become saturated as before, when the operations of drawing off and changing the liquid are repeated.

By this arrangement of the chamber two important objects are secured: first, the exposure of that portion of the liquid which is nearest the point of saturation, and which in consequence absorbs the gases with the greatest difficulty, to the sulphurous and nitrous vapours, where they exist in the most concentrated state; and, secondly, the ensuring a complete absorption of the sulphurous fumes, by exposing them, before they leave the chamber, to a portion of fresh, or but slightly impregnated, water. The same principles apply, of course, to the intermediate compartments.

Such is Dr. Hempel's chamber: there can be little doubt but some arrangement of the kind may be made to increase the rapidity of absorption; but it may be a question whether the advantage would be such as to indemnify the manufacturer for the additional expense and the greater liability to derangements of so complicated an apparatus as the one just described. Various simplifications will occur to the practical chemist on a moment's reflection, which may still embrace its leading principles. Manufacturers of oil of vitriol, who happen to have two or more chambers contiguous or near each other, but upon different levels, may avail themselves of them by forming communications between them with a flue, for ventilation at the extreme of one chamber of the series, and a furnace at the other. Such an arrangement, indeed, the writer is well informed, has actually been made in an extensive oil of vitriol work in Liverpool, and with satisfaction to the proprietor. The change from the common plan to the new, including the substitution of the new method of constant combustion, for the old would be attended with a very trifling expense. Many chambers, indeed, would require no alteration whatever; for they are now very generally provided with chimneys or flues for occasional ventilation, and the fire-place, which is now usually situated without the chamber, need only be left open in the first chamber in the series, and closed in the others.

The arrangement for boiling water over the fire-place, as represented at A, in fig. 234, and already described, is not peculiar to Dr. Hempel's chamber. It is the invention of a Swiss manufacturer, and has not before been made public. It is a very simple and effectual method of introducing steam into the chamber; and as the amount of evaporation must depend directly upon the rapidity of the combustion and the quantity of sulphurous and nitrous gases produced, by varying the size of the pan over the fire-place, the quantity of steam may be regulated to any mea-

sure, and will always bear the same proportion to the sulphurous fumes. But the utility of the arrangement depends on the general question, not yet settled, how far steam, under any circumstances, is favourable to the formation of sulphuric acid from the sulphurous and nitrous gases over water.

Fig. 235 shows a simpler method of drawing the liquid from one compartment to another of a chamber on Dr. Hempel's plan, than the one represented at *i i i i*, in fig. 234, and less liable to fall out of repair; the patulous extremity of the lower tube is above the surface of the liquid in the lowest compartment. When the liquor is drawn from the upper chamber, and a fresh portion is to be introduced, the leaden tube, *a*, need only be bent so as to bring its outer extremity above the level of the liquid within the chamber, and all is secure. The furnace, or fire-place, A, in all its dimensions, and the height of the chamber, B, of fig. 234, is drawn to a scale of eight feet to an inch; but the length of the chamber to a scale of sixteen feet to an inch, to accommodate the plate.]

In case of the sulphuric acid being rendered impure by any accidental circumstance, the best method of divesting it of its impurity is by a fresh distillation. This is generally performed in a glass retort. It must be observed, however, that if green glass is employed the retort is apt to crack in the middle of the process; even flint glass retorts will crack if the sand rise round them higher than the evaporable charge. Hence a capella vacua is preferable to the ordinary sand-bath.

The watery fluid which first distils over on this occasion may be received in a separate vessel, and another fitted on the instant a strong acid begins to come over. By this means the acid is procured in its pure state, and such it is required to be for accurate and exact chemical experiments.

There is another way proposed by some, which, however, is very defective, of purifying a dark-coloured oil of vitriol.—This consists in merely boiling it up in a glass retort, and suffering it afterwards to grow cold, and to clear itself slowly and by degrees.

The acid becomes colourless and limpid like water; but it may nevertheless contain various extraneous particles, which cannot by this means be separated from it. Upon a similar decomposition of the combustible matter is founded, also, the following method of purification; viz. from half an ounce to six drams of nitre are mixed with one pound of dark-coloured oil of vitriol, and the mixture is heated to the boiling point, or till the dark colour disappears. In each of the latter cases the sulphuric acid is at the same time rendered impure in another way.

On rectifying the oil of vitriol, as well as in the second purification of it, there is found an earthy saline sediment, which is more or less abundant, in proportion to the impurity of the oil. In the Nord-hausen, and other similar oils of vitriol, which are produced by the distillation of vitriol, this kind of impurity is usually very trifling; but in the English oil of vitriol it is very considerable, on account of the acid being prepared with-

out distillation; and, indeed, in the way in which that is prepared it is possible for contaminations of various kinds to take place, particularly of sulphate of potasse and sulphate of lead.

Berzelius has found traces of titanium in English oil of vitriol, and of selenium in the Swedish.

For the purpose of analysis, it will be convenient to keep not only the concentrated acid, but also some of the specific gravity of 1,135, as one dram measure of this will saturate two dram measures of potasse water at 1,100; two of soda water at 1,070; one of ammonia water, at 0,970; one of sub-carbonate of potasse water, at 1,248; two of sub-carbonate of soda water, at 1,110; and two of sub-carbonate of ammonia water, at 1,046.

### *Uses of Sulphuric Acid.*

This acid is extensively used in the chemical arts, particularly in bleaching, and some of the processes of dyeing. It is also used to separate the acids of nitre and common salts from their bases, and on numerous other occasions. In medicine a few drops are exhibited as a tonic, and it is by some used as a caustic to fresh wounds.

The composition of the strongest oil of vitriol, specific gravity 1,847, is supposed to be one atom of sulphur with three of oxygen and one of water, being the sulphas hydricus of Berzelius, S:·+HH·, that chemist supposing the water acts as a base. The anhydrous or dry acid, acidum sulphuricum of Berzelius, is S:·; but according to Dulong's opinion this last is not an acid, but merely the basis, which is converted into the sulphuric acid by decomposing water, so that the composition of the sulphuric acid is really S:: H, as Dulong esteems water as H· only.

On the Stahlian theory sulphur is S H, and oil of vitriol S O + 33 Aq.; the glacial or icy oil, or anhydrous acid being S O + 24 Aq.

According to Mr. Dalton and Dr. Thomson, the specific gravity of the acid combined with water is as follows: one proportion or atom of acid, with

| | | |
|---|---|---|
| 1 | of water - | 1,850 |
| 2 | - - | 1,780 |
| 3 | - - | 1,650 |
| 10 | - - | 1,300 |
| 15 | - - | 1,220 |
| 17 | - - | 1,200 |
| 38 | - - | 1,100 |

Dr. Percival, Trans. Roy. Ir. Acad. found that by dissolving two Troy ounces of sulphate of potasse in nine ounce measures of oil of vitriol, at 1,845, the specific gravity was raised to 1,892; so that the specific gravity is not to be trusted as a test of the strength of the acid; but recourse must be had to the saturation of carbonate of soda.

Some manufacturers take it out of the chambers when it acquires the specific gravity of 1,220, others let it remain till it

becomes 1,500. It is concentrated in the leaden boilers up to 1,750, but then it must be removed into glass or other vessels.

### *Sulphurous Acid Water.*

This acid is procured extemporaneously by burning brimstone in a closet for bleaching straw hats, or by taking a rag, dipped in melted brimstone, and burning it in the cask to stop the fermentation of wine; but the neatest process is to prepare the acid water, formerly called, in the Pharmacopœia, gas sulphuris.

One pound of wood shavings is put into a glass retort, and there is then added a pound of oil of vitriol: to the retort, placed in a sand-pot, is then luted a receiver, containing sixteen pounds, or two gallons of water, to receive and condense the acid gas, the fire is then lighted and the distillation continued to dryness.

Some use saw-dust, chopped straw, or charcoal dust, instead of wood shavings, but these are apt to get lumpy; for theoretical purposes, quicksilver or tin is employed, by which the admixture of carbonic acid is avoided.

Instead of a retort and receiver, a glass matrass and a bent hollow glass cane, forming a communication with a bottle or jar, may be used.

The proportion of water stated above, causes the acid to be of a proper strength for bleaching, but some prefer putting only four pounds of water into the receiver, and thus procure a less bulky product, which they afterwards weaken with more water, if it is to be used for bleaching, but for stopping the fermentation of wine the strong acid is preferable.

This acid is also used for discharging stains and iron moulds from linen. It must be kept in small, well-stopped bottles, or used soon after it is made: for the action of air speedily changes it into sulphuric acid.

Berthier produces this acid by heating one ounce of sulphur with eight of black manganese; receiving the gas in water, as in the former process.

### *Liquid Sulphurous Acid.*

This acid is obtained by distilling oil of vitriol with quicksilver, or tin, and passing the gas through a hollow glass cane, filled with muriate of lime, into a small matrass, surrounded by a freezing mixture of two parts of ice and one of common salt.

This acid is so extremely volatile that it may even be used to produce so intense a degree of cold, that M. Bussy has condensed, by its means, not only chlorine gas, and ammoniacal gas, but also cyanogen.

## NITRIC AND NITROUS ACIDS.

The nitric and nitrous acids are usually confounded together, and, indeed, are prepared by the same process, and mixed together. Nor is this mixture of any detriment to the generality

of operations in which they are employed, for the nitrous acid is changed, during the operation, into the nitric.

They are distinguished by the manufacturers into several kinds, according to their mode of preparation. If made by distilling saltpetre with copperas, it is called *aqua fortis;* if with clay, a process not now used in England, *spirit of nitre;* if with oil of vitriol, *Glauber's spirit of nitre*, or *nitrous acid;* if this is rendered colourless by boiling, *nitric acid.*

The processes for preparing these acids remain the same as at their first invention, and do not seem to admit of any improvement.

### *Aqua Fortis.*

To obtain the common nitric acid called aquafortis, equal parts of well purified nitre and copperas, or green vitriol, are taken. The nitre is dried, and the vitriol is calcined to redness. These two substances are well mixed together. The mixture is then put into an earthen retort, or an iron pot, with a stone-ware head, of such a size that they may be but half full.

The retort, if used, is set in a reverberating furnace, and in either case, a large glass receiver, having a small hole in its body, stopped with a little lute, or a safety-pipe, is applied. This receiver is luted to the retort with the fat lute. and the joint covered with a slip of canvass, smeared with lute made of quicklime and the white of an egg. The vessels are heated gradually; the receiver is soon filled with very dense red vapours.

In order that the redundant vapours may be let out, the small hole in the receiver must be opened from time to time. Towards the end of the operation, the fire must be raised so that the vessel is made red. When it is found, even if the retort be red hot, that nothing more comes over, the vessels are left to cool, and the receiver is unluted, and, without delay, the liquor it contains is poured into a bottle.

This liquor, being nitrous acid, is of a reddish-yellow colour, smokes exceedingly, and the bottle containing it is constantly filled with red fumes, like those observed in the distillation.

By this process a very strong and smoking spirit of nitre is obtained. If the precautions of drying the nitre, and calcining the vitriol, be neglected, the acid that comes over, greedily attracting the water contained in these salts, will be very aqueous, will not smoke, and will be almost colourless with a very slight tinge of yellow, and is sold by the name of single aqua fortis.

The fumes of highly concentrated nitrous acid, such as that obtained by the above process, are corrosive, and very dangerous to the lungs. The person, therefore, who unlutes the ves-

sels, or pours the liquor out of the receiver into the bottle, ought, with the greatest caution, to avoid drawing them in with his breath; and, for that reason, ought to place himself so that a current of air, either natural or artificial, may carry them off another way. It is also nccessary that care be taken during the operation, if you do not use a safety-pipe, to give the vapours a little vent every now and then, by opening the small hole in the receiver; for they are so elastic that, if too closely confined, they will burst the vessels.

When the operation is over, a red mass is left at the bottom of the retort, cast as it were in a mould.

Thc ferruginous basis of the vitriol, which is mixed with this salt, the sulphate of potasse, gives it the red colour. To separate the sulphate from the mass, it must be pulverized; dissolved in boiling water, and the solution filtered several times, to separate the red oxide of iron, which being very finely divided, is sold for polishing metals, under the names of colcothar, trip, or rouge. When the solution is very clear, and deposites no scdiment, it is set to shoot, and will yield crystals of sulphate of potasse, to which a German physician gave the name of sal de duobus, but which is sold now under thc name of sal enixum, a name given to it by Paracelsus.

### *Spirit of Nitre.*

The foreign distillers of aqua fortis, who make large quantities at a time, and who use the least chargeable mcthods, do their business by means of earths holding a quantity of sand, such as clays and boles. With these earths they mix the rough saltpetre, from which they intend to draw their spirit. This mixture they put into large oblong earthen pots, having a very short curved neck, which enters a receiver of the same matter and form.

These vessels they place in two rows, opposite to each other, in long furnaces, and cover them over with bricks, cemcnted with loam, which scrves for a reverberatory. Then they light the fire in the furnace, making it at first very small, only to warm the vesscls. They then throw in wood, and raise thc fire till the pots grow quite red hot, in which degree they keep it up till the distillation is entirely finished.

Thc acid obtained in this process is less highly coloured than the acid obtained by copperas, and, as rough saltpetrc is usually employed, it contains much muriatic acid.

Thc residuum is, in Francc, ground to a powder, and uscd as a red sand, in thc alleys of artificial gardens, to vary the colours of the paths; it is also used in ccments.

### *Glauber's Spirit of Nitre, or Nitric Acid.*

The acid of nitrc is also commonly separated from its basis

by means of the pure sulphuric acid. For procuring it in a small quantity, refined saltpetre is finely pulverized, put into a glass or stone-ware retort, and a third, or rather half of its weight of concentrated oil of vitriol poured on it. The retort is placed in a furnace, and a receiver expeditiously applied.

As soon as the oil of vitriol touches the nitre, the mixture grows hot, and copious red fumes begin to appear. Some drops of the acid come over even before the fire is kindled in the furnace.

On this occasion the fire must be moderate; because the vitriolic acid being clogged by no basis, acts upon the nitre much more briskly, and with much greater effect, than when it is not pure.

This operation may be performed by a sand heat, which is a speedy and commodious way of obtaining the nitrous acid. In other respects, the precautions recommended in the process for aqua fortis, must be carefully observed here, both in distilling the acid, and in taking it out of the receiver.

This spirit of nitre may also be prepared in an iron pot with a stone-ware head, and a receiver of the same ware; but there should be a white glass adapter between the head and receiver, that the progress of the operation may be seen.

The French now distil it in large cast-iron cylinders, the same apparatus as is hereafter described for preparing the muriatic acid, except that four cylinders are usually heated by the same fire, and only three or four receivers attached to each.

When distilled in an iron vessel, a greater portion of the product is in the state of nitrous acid than when distilled in glass or stone-ware with no more heat than is necessary. To obtain the real nitric acid, it is only necessary to heat the acid in a glass retort, until it becomes as clear as water, by the flying off of the nitrous gas.

The quantity that is condensed in water during the distillation of this acid spirit, when Glauber's apparatus is used, is, as Mr. Woulfe observes, so small that it would be scarcely worth saving, if it was not to prevent those noxious fumes of nitrous gas which have such an effect on the lungs of the operator, as frequently to make him spit blood. Water highly charged with these fumes by repeated distillations becomes blue, and retains its colour. Mr. Woulfe distilled, in an iron body with a stone-ware head, thirty pounds of nitre, with sixty pounds of green vitriol, which he had calcined to whiteness, and made use of two vessels of water, as in fig. 147, to condense the vapours. This water became blue in one distillation, and continued so for eighteen months till he made use of it. A great quantity of gas was set free from the beginning to the end of the distillation, owing, in a great measure, to the acid fumes acting on the iron

body; for if distilled in a glass or stone vessel, the quantity of this gas is not near so considerable. The water in which these nitrous fumes were condensed, saturated more alkali than the strongest oil of vitriol. The water was not heated by these fumes.

When oil of vitriol was used in this operation to set free the acid of nitre, Mr. Woulfe found on trial the fumes condensed in the water to be pure spirit of nitre; whereas, in the other operation, where calcined vitriol or copperas was used, the fumes contained some acid of salt. This led him to examine the common English green copperas, and he found it contained a portion of iron united to the acid of salt; whereas the Dantzic copperas or vitriol, contains no acid of salt; and this is the reason why it is preferred for making aqua fortis for the refiners' use, and for dyeing certain colours; and still used by the Dutch and some English manufacturers instead of the common copperas.

[The English manufacturers now procure the aqua fortis, or nitric acid, of commerce almost exclusively by the direct action of sulphuric acid on the nitrate of potash. The indirect method of obtaining this article from nitre and the green copperas, is more expensive at the present low prices of sulphuric acid, and the product is never so pure. When nitre is heated with calcined per sulphate of iron, a portion of the acid is decomposed and resolved into nitrous acid and oxygen: the latter unites with the iron, converting the protoxide into a peroxide, and the former passes over into the receiver along with the nitric acid, imparting to it a reddish colour, and the fuming property mentioned in the preceding article.

The cylinder is found to be the most useful form for the retort, both for distilling the nitric and the muriatic acids, on account of the greater convenience of removing from it the materials remaining in the retort after distillation. But a decided improvement on the French cylinder, as represented in fig. 236, has been introduced by an English manufacturer, which secures the advantage of the cylindrical form, and obviates, in a great degree, the objection to the employment of iron vessels. This improvement consists in constructing the upper half of the cylinder of bricks laid in Roman cement. Fig. 236 represents a front elevation of two retorts constructed on this plan; *a a*, the retorts, which are usually made six feet long, and one foot six inches in diameter in the clear; the lower half are of cast-iron, about one and one-half inches thick; these semi-cylinders of iron have horizontal flanges, *c c c c*, running the whole length of the retort, and about-four inches wide: these flanges are slightly turned up at the edge, and constitute abutments, from which an arch of brick work is sprung, which forms the upper half of the retort, and completes the cylinder. The cylinders are sup-

ported only at the ends, and set in such a way as to allow the fire to come in contact only with the iron surface; the brick work above is left exposed so as to allow the operator to detect any leakage, which may occur during the operation. The ends of the retorts are closed by iron lids, and the arrangements in every other respect are quite similar to those delineated in fig. 104.

The cheapest receivers on a large scale are fabricated of fine clay, and glazed with common salt, forming that species of pottery which is generally known in this country by the name of stone-ware; the best form is that of a cylinder set on end, with two patulous lipped tubulures at the top for the reception of tubes of the same material twice bent at right angles, by which the receivers are connected together. The receivers may contain from 12 to 20 gallons each, and cost one shilling and six pence sterling per gallon in England. About 12 receivers are usually connected with each retort of the above dimensions. The junctures are all secured with Roman cement. 350 pounds of crude coarse nitre are put into each retort, and after the iron ends are luted in, 210 pounds of concentrated sulphuric acid are introduced through a tubulure in the upper part of the lid, or end, by means of a leaden funnel, with a long bent tube, which conducts the acid to the middle of the retort, from which it may flow equally to either end. The tubulure is then stopped and luted. Previously, however, to the introduction of the acid, the first receiver of the series is connected with the retort by means of an earthen pipe, and the receivers with one another. No water is put in the first five receivers: into the remaining seven, 32 gallons of water are introduced and distributed as follows: 2 gallons in the sixth, 3 in the seventh, 4 in the eighth, 5 in the ninth, and six gallons in each of the remaining three: no water is put in the first receivers, in order that the product may be more free from nitrous acid, for the more concentrated the nitric acid is, the less nitrous acid will be absorbed. The same reason obtains for using the concentrated instead of a diluted sulphuric acid in the distillation.

It is very important to the success of this distillation that the nitrate of potash be free from the muriate soda, a very common impurity. A ready test of the purity of nitre in this respect is afforded by the action of sulphuric acid upon it when cold; if the salt effervesce on the addition of concentrated oil of vitriol, the presence of muriate of soda is altogether probable; if a solution of the salt give a white precipitate with the nitrate of silver, there can be little doubt of the fact; the muriate of potash and other salts might afford the same results, but they are rarely present in the nitre of commerce. The muriate of soda not only contaminates the product, but frequent-

ly occasions such an effervescence of the materials in the retort as to drive over the mixture, and ruin it altogether.

In order to secure a little pressure on the mixture in the cylinder, the diameter of the pipe connecting the two last receivers in the series should not exceed one inch: the diameter of the other connecting tubes (in the clear) should be about 2 inches.

After the distillation is finished, the specific gravity in the five first receivers, will range from 1.460 to 1.475. The product in the last seven receivers will be of various specific gravities, and is used to dilute that in the first four. The acid in the first receiver should never be sold by the manufacturing chemist, and is usually reserved for other processes of chemical manufacture. That in the other receivers is very free from sulphuric acid, but is contaminated to a greater or less degree, with nitrous acid. In order to remove this impurity, reduce the acid to 1.380, by the addition of water, or by the mixture of the weaker with the stronger products of distillation, pour it back into the receivers, and expose them to the heat of a hot water bath for 10 or 12 hours. Some chemists fill the receivers to within six inches of the top, and connect them by the bent tubes with others containing eight gallons of water each, by which the nitrous acid is condensed and saved; or where there is an oil of vitriol chamber, the fumes of nitrous acid may be profitably conducted into that, and thereby make a considerable saving of nitre.

The nitric acid of commerce is sold under the name of single, double, and triple, aqua fortis; the first should have a specific gravity of 1.180, the second, of 1.320, the third, of 1.360, or reckoning on Twedale's hydrometer, the numbers should be 36°, 64°, and 72°. The caput mortuum, after the distillation of nitric acid, was formerly known and still goes by the name of sal enixum with the practical chemists. It consists for the most part, of the sulphate of potash, a salt for which there is some demand for the calico printers. To prepare this salt, put into a leaden boiler capable of holding 25 gallons, 15 gallons of water, 28 pounds of sal anixion, and 18 pounds of sulphuric acid; boil this mixture, and then add as much more of the salt and acid in the above proportions as will be necessary to raise the liquid to the specific gravity of 1.200; while hot, run off the liquid into a leaden vessel, and when the foreign matters have subsided, pour the clear liquor back into the boiler and evaporate to 1.500 (when cold, i. e. at 60°.) Lastly, lade the liquor into a leaden pan sitting upon the warm brick-work, and suspend in it slips of lead; allow the liquor to cool very slowly; the crystals of super-sulphate of potash will form upon the slips of lead and the sides and the bottom of the pan. It is important that the cooling should be gradual, as otherwise there

will be instead of crystals a pasty pulpy mass. The mother water is unfit for use a second time, on account of the presence of iron. For other dispositions of the sal anixion, see the articles muriatic acid and alum, in this work.

### *Pure Nitric Acid.*

The nitric acid extracted by Glauber's process is as strong as that obtained by calcined vitriol, provided the oil of vitriol made use of be well concentrated; but it is also generally tainted by the admixture of a small portion of the sulphuric acid, which is carried up by the heat, and if the saltpetre was not properly refined, with muriatic acid.

There are several processes in chemistry that succeed equally well whether the nitric acid be or be not thus adulterated with a mixture of the sulphuric acid. But most experiments require the nitric to be absolutely pure; and if it be intended for such, it must be perfectly cleansed from the sulphuric taint.

This is generally effected by mixing the acid with very pure saltpetre, and distilling it a second time. The sulphuric acid, with which this spirit of nitre is adulterated, coming in contact with a great quantity of undecomposed nitre, unites with its alkaline base, and expels a proportionable quantity of the nitric acid.

The separation of the muriatic acid is more difficult; if the nitric acid is strong, it may be mixed with nitric solution of silver, which causes an insoluble muriate of silver to fall down as a sediment; but this will not answer well if the nitric acid is weak.

If, as some authors order, the impure nitric acid is mixed with nitric solution of silver, and distilled to dryness, the last portions of acid carry over with them some traces of the muriate of silver.

Another process has been tried to effect this purification by distilling the acid from the scaly yellow oxide of lead, called litharge. A process which has occasioned much discussion. M. Steinacher observes, that it has been long known that the last portions of nitric acid distilled on litharge contain muriatic acid. Berthollet explains this phenomenon by saying that the oxide of lead dividing its action between the two acids, both are subject to the action of the expansibility produced by heat.

When the nitric acid has been sufficiently concentrated before it is submitted to rectification on oxide of lead, the first portion of the rectification contains no muriatic acid, notwithstanding the nitric acid contains much of the former before its concentration. The excess of water is the true cause that diminishes the attraction of the muriatic acid for the oxide of lead. It would, however, be vain to expect success in concentrating

the acid before it is rectified, by taking a certain quantity of litharge, or by distilling to dryness, as many authors have prescribed. The quantity of litharge ought to vary from one-sixteenth to one-half of the weight of the acid, according to its degree of impurity. On the other hand, by distilling to dryness the last portions of nitric acid, carry over with them muriate of lead. The following process may be useful to those who wish to prepare themselves the reagents with which they operate:

Eight pounds of nitric acid, at 35° containing muriatic acid, and a very small quantity of sulphuric acid, must first be distilled in a capella vacua. The fire also must be managed in such a manner that the drops may slowly succeed each other, and the distillation stopped when half the acid is come over. This rectified acid will mark 15° on Baumé's hydrometer. What is left in the retort is 40° of the hydrometer: throw into it litharge in fine powder, and stir it with a glass stick. A few hours are sufficient to convert the litharge into a white powder. Put in more, and keep adding farther quantities till you see that it preserves its colour after being immersed several hours. Then let the muriate and sulphate of lead entirely settle, and decant the acid into a glass retort set in a capella vacua, on a little sand, to keep it steady.

Adapt to the retort a receiver that fits exactly without being luted, for as the vapour of the acid easily destroys every kind of luting, the produce would be liable to be dirty, and conduct the distillation very slowly; yet care must be taken to keep the acid boiling, as it otherwise would disperse in vapours that could not be condensed. The first half that comes over marks 35° of Baumé's hydrometer, and the second 40. Both portions are colourless, and possess all the properties of very pure nitric acid, provided the precaution be observed to leave one-thirty-second of the liquid in the retort.

The following table, from a set of experiments which Dr. T. Thomson made with great care, exhibits the specific gravity of various atomic compounds of real nitric acid and water. One proportion or atom of acid with

| | |
|---|---|
| 1 of water . . | 1,550 |
| 2 . . . | 1,4865 |
| 3 . . . | 1,4546 |
| 4 . . . | 1,4237 |
| 5 . . . | 1,3928 |
| 6 . . . | 1,3692 |
| 7 . . . | 1,3456 |
| 8 . . . | 1,3420 |
| 9 . . . | 1,3032 |
| 10 . . . | 1,2844 |
| 11 . . . | 1,2656 |
| 12 . . . | 1,2495 |
| 13 . . . | 1,2334 |
| 14 . . . | 1,2173 |
| 15 . . . | 1,2012 |

The acid compound, of one proportion of acid and four of water, seems to be the most intimate, for its boiling temperature is the highest, being 248°, while acid, both stronger and weaker than this, boils at a lower temperature. This is the strength of the acid usually sold, and 100 parts of it contains exactly sixty of real acid, and forty of water.

Acid of the specific gravity 1·3692, contains just half its weight of water; it boils at the temperature of 243°.

These boiling points were determined by Mr. Dalton.

Nitric acid is usually kept not only in a concentrated state, but also of a proper strength for the solution of silver without heat; that is, of the specific gravity 1,108, or so that a bottle that will hold sixteen ounces of water holds nineteen of the acid. Henry recommends analytical chemists to keep their acid at 1,143, so that it may have the same power of saturation as sulphuric acid, at 1,135.

Nitric acid is considered as a compound of one atom of azote, or nitrogen, with five of oxygen, or Az:::, and its proportional number, according to Thomson, is, 6,750. Berzelius considered it as a combination of nitricum and six volumes of oxygen, N:::, or 677,260, which is the same in effect, because he considers azote or nitrogen to be the oxide of a hitherto unseparated basis, which he calls nitricum.

Pure nitrous acid contains an atom less of oxygen, and its proportional number, is, of course, either 5,750, or 577,260. When mixed with water it is converted into nitric acid and nitrous gas.

What is commonly called nitrous acid is generally considered as merely nitric acid impregnated with nitrous gas; but it seems to be rather a mixture in various proportions of nitric and nitrous acids, the oxygen dividing itself between them.

The pure nitrous acid is not used.

## MURIATIC ACID.

This acid is also called *the acid of common salt*, as it is always extracted from it; and as common salt is often made from sea water, the acid also got the name of *marine acid*. It is now called *hydrochloric acid* by the theoretical chemists.

The common salt from which the acid is to be extracted is put into a glass retort, leaving two-thirds of it empty. The retort is set in a furnace, and a receiver, with a hole in its side, applied and luted on. Then through the hole in the arch of the retort, a quantity of oil of vitriol, equal in weight to about a third part of the salt, is poured, and immediately the hole shut very close.

As soon as the oil of vitriol touches the salt, the retort and receiver will be filled with abundance of white vapours, and soon after, without lighting any fire in the furnace, drops of a yellow liquor will distil from the nose of the retort. The distillation is to proceed in this manner without fire, as long as any drops are perceived. A very small fire is next kindled under the retort, and the fire gradually raised by very slow degrees

and with great caution. The distillation will be ended before you have occasion to render the retort red hot. The vessels are then unluted, and the condensed liquor which will be found to be a very smoking spirit of salt, is kept under the distinctive name of Glauber's spirit of salt.

As oil of vitriol is used on this occasion, and as the sea salt is generally dried, the acid obtained from it by distillation is very free from moisture, and always smokes even more violently than the strongest acid of nitre. The vapours of this acid are also much more elastic and more penetrating than those of the nitrous acid.

This process requires a pierced retort, that the oil of vitriol may be mixed with the sea salt after the receiver is well luted to the retort, and not before. For as soon as these matters come together, the muriatic acid gas rushes out with so much impetuosity that, if the vessels were not luted at the time, the copious vapours that would issue through the neck of the receiver would so much moisten it, as well as the neck of the retort, that it would be impracticable to apply the lute and secure the joint as the operation requires. The operator would besides be exposed to those dangerous fumes which on this occasion rush out, and enter the lungs with such incredible activity as to threaten instant suffocation.

When the operation is finished, a white mass is left at the bottom of the retort, which is the sulphate of soda, or Glauber's salt.

Spirit of salt, drawn by the process above described, is tainted with a small mixture of the sulphuric acid, carried up by the force of fire before it had time to combine with the soda of the salt: in order to free it from this sulphuric acid, it must be distilled a second time from sea salt.

Brugnatelli, in making muriatic acid for theoretical purposes, uses eight ounces of dry common salt, and five of oil of vitriol, passing the gas through a bent syphon, containing muriate of barytes, to absorb the sulphuric acid that may distil over. He also puts eight ounces of water into the receiver; and finds that water absorbs 450 times its bulk of muriatic acid gas, by which the bulk of the water is augmented about one-third.

Three apparatus are used for manufacturing muriatic acid, on a large scale, from common salt and oil of vitriol.

Some manufacturers, both in England and France, use a cast-iron pot set in a furnace, instead of a retort. In England this pot is covered with a pierced stone-ware head, and connected with a large receiver of the same ware, in which water is placed. But in France the pot is covered with a plate of lead, screwed down upon it, and is connected with a row of seven or eight stone-ware bottles, by means of bent pipes. These bottles are each half filled with water.

Fig 103

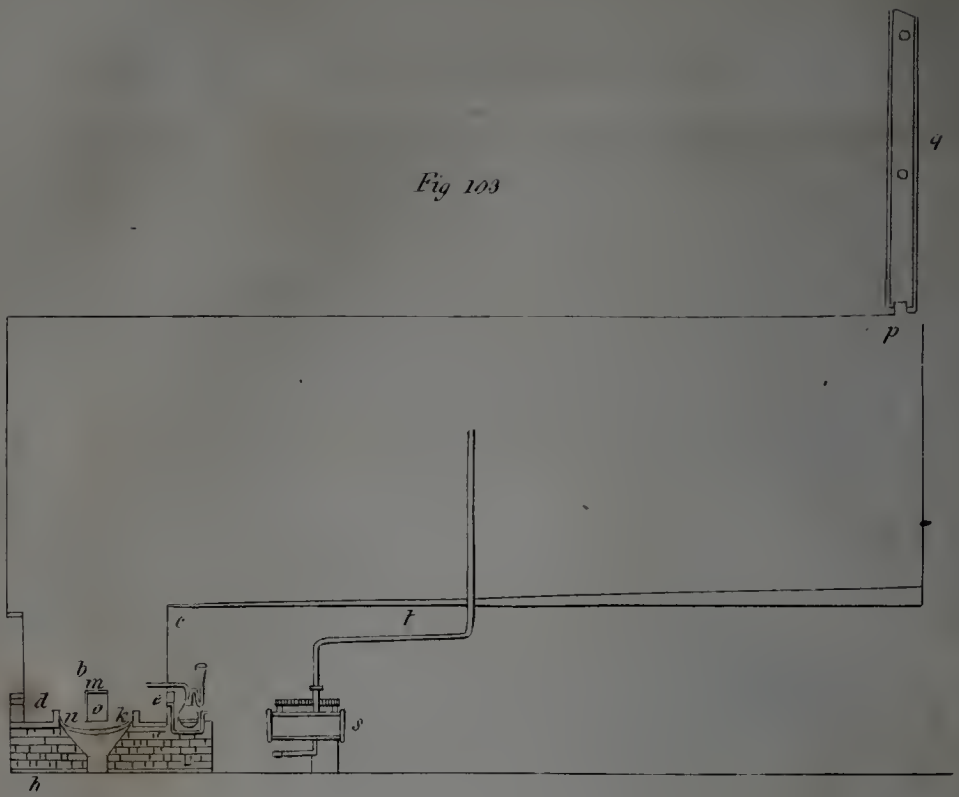



Fig. 104.

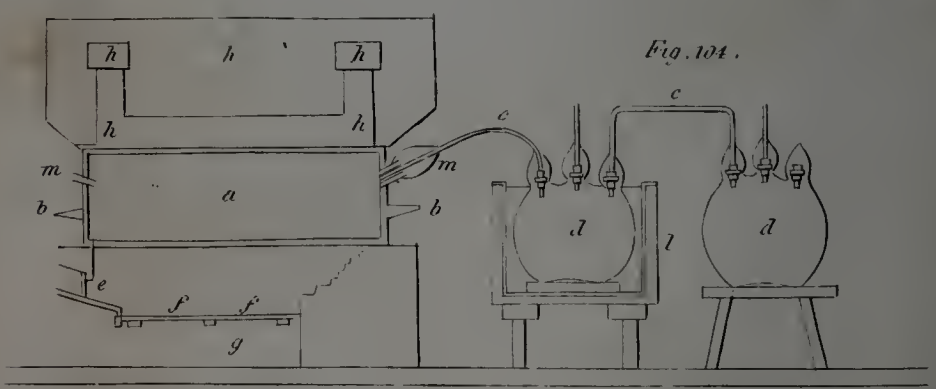
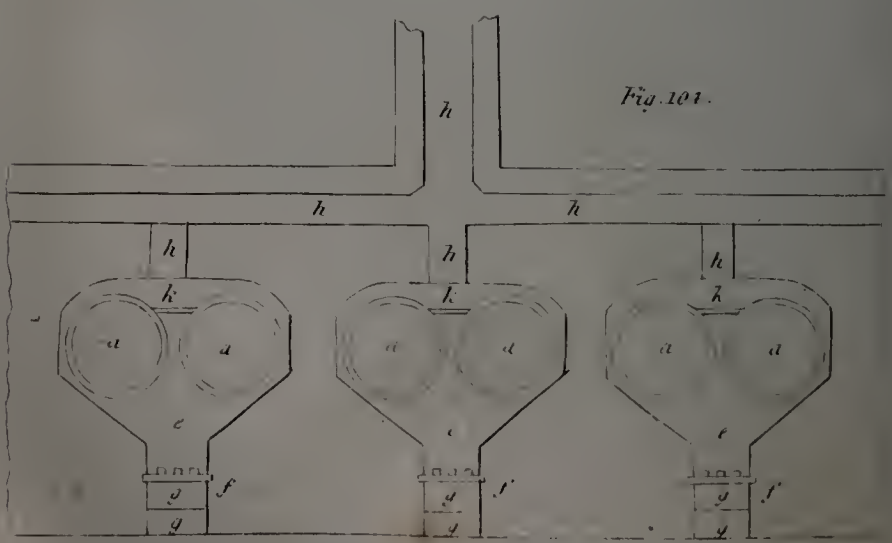



Fig. 104.



The salt being put into the pot and the head and receiver luted to it, or the plate of lead screwed down, and the pipes luted to it and the bottles, the oil of vitriol is poured by a funnel through the hole left for the purpose.

This method is subject to the inconvenience of the saline residuum concreting so fast to the bottom of the pot that it is very difficult to be detached.

The second apparatus is used in France, and called by the French the appareil des bastringues. It is connected essentially with the manufactory for mineral alkali, and the muriatic acid is only a secondary product.

At the back of a reverberatory furnace with a chamber on the side, as in fig. 14, a large leaden pan, about six feet long, five feet wide, and a foot deep, is set in the brick-work and covered with plates of cast iron, level with the lower edge of the flue coming from the chamber, so that the flame, &c. passes over these plates, then under the pan, and up the sides, from whence they enter the flue of the chimney, of course the pan is heated by the waste heat of the furnace. An opening is left on one end of the pan, by which it is charged with salt, usually twelve sacks of two hundred pounds each, after which the opening is closed with care. Sulphuric acid at 54° Baumé, in the proportion of one hundred and ten pounds for each one hundred pounds of salt, is then poured in by a pipe. The vapours pass through four earthen-ware pipes into the condensors, which are seven or eight stone-ware vessels without bottoms, placed one upon another, so that the acid as it passes upon them may be condensed, and drip down to the lowest, whence it runs into the bottles in which it is sold.

At the expiration of a certain time, the opening at the end of the pan is unclosed, and the soft pasty residuum is drawn out, on a brick hearth, where it soon becomes solid: this part of the operation is very distressing to the laborants, on account of the muriatic acid gas which it continues to emit, as it is impossible to finish the decomposing the common salt entirely in this method, from the necessity of withdrawing the residuum while it is yet soft. In this process there is only obtained two-thirds of the acid contained in the salt, or about eighty or ninety pounds of weak acid at 21° Baumé, from each one hundred pounds of salt.

Some manufacturers instead of aludels use long troughs of brick-work, or subterranean sewers, lined with glazed tiles, and having a current of water running through them in a contrary direction to the passage of the vapours; but this was for the purpose of getting rid of the acid, when it was produced in a greater quantity than the market required.

The third apparatus is an extension of the use of cylindrical

## iron long necks instead of retorts, which have come so much into use in manufactories.

A furnace, fig. 104, is constructed capable of containing twenty cylinders, *a*. They are made of cast iron, of a homogeneous texture, and uniform thickness, in order to prevent unequal expansion and cracks. They are placed in pairs in the furnace, and each pair has its fire-place, *e;* grate, *f;* and ash-room, *g;* somewhat like the apparatus for making coal gas. Every part of the cylinder should be equally heated, in order that the decomposition of the salt may be simultaneous, and the iron be as little as possible injured by the acid. For this purpose, a plate of cast iron, *k*, is placed between the cylinders; and the flues, *h*, are constructed so as to produce an equal draught through every part of the furnace. In proportion as the sulphuric acid contains less water, and in proportion as the cylinder is heated, it is less subject to be injured by the acid. The flame should envelope every part of the cylinder, and should be retained in the archway above it, to give out some of its heat before it flies up the chimney.

Each cylinder is closed at both ends by a plate of cast iron entering just within the cylinder, where it meets with a circular rim. Each plate has a handle of cast iron, *b*, and a small tube, *m*, projecting upwards, and being in the upper part, for the purpose, at one end, of pouring in the sulphuric acid, and conveying off the product at the other. The first cylinder communicates by the bent pipe, *c*, either of glass or earthenware, with the earthen vessel, *d*, which has three mouths, and again communicates by two other bent tubes, *c*, with two other vessels of the same description. All the gas not condensed in the first bottle, *d*, passes into the other bottle, and at the same time, the second bottle, *d*, receives the gas from the second cylinder, and transmits what it does not condense to another bottle of the same description, which in like manner also receives the gas from the third cylinder, and in this way the process goes on to the last bottle, which receives the gas not condensed in all the others, and, moreover, that which issues from the last cylinder. From this, whatever is not condensed is again transmitted through a second range of bottles, consisting, perhaps, of twenty, till the whole is condensed. It is proper to place the first range of bottles in a trough, *l*, through which a stream of water flows gently and constantly, cooling the bottles, and getting itself heated.

The purest muriatic acid is obtained in the second range of bottles. That which is condensed in the first series always contains a little sulphuric acid, and sometimes sulphate of soda and muriate of iron. All these bottles are to be half filled with water, which will absorb two-fifths of its weight of muriatic acid. By means of this apparatus, 130 parts of muriatic acid, of the specific gravity 1·190, may be obtained from 100 of common salt. Each cylinder is charged with about 160 pounds of common salt, and the end is then luted with clay, the fire is kindled, and the sulphuric acid poured on the salt, in the proportion of eighty pounds of acid, to 100 of salt; if the acid is concentrated to 66° of Baumé's areometer, and 83 to 100 if it is only concentrated to 64°. The fire should be made brisk at first, and be lessened immediately the distillation begins; when this slackens, the heat is increased; afterwards, the end is removed, the sulphate of soda taken out, and the process is then repeated. By means of syphons, the muriatic acid is drawn into bottles, or jars, covered with basketing; its strength is 23° of Baumé, and in this state it is sent into the market.

[The cylindrical retorts already described in the preceding article (see also Fig. 236) are preferable to those composed wholly of iron for the distillation of muriatic, as well as for the nitric, acid. They combine the peculiar advantages of the cast-iron pots with stone-ware, or leaden caps with those of the iron cylinders. The same kind of receivers also, as recommended in the distillation of nitric acid will be found very convenient and economical for this purpose. Fig. 237 exhibits a ground view of the manner in which the receivers may be arranged and connected together for this purpose; *a a* are the earthen tubes leading from two cylinders and terminating in the receiver *b;* this receiver is connected with the usual bent earthen tubes with the receiver *c*, this last with *d*, and so on through the series, which terminates in the receiver *e*. About 20 re-

*Fig. 236.*

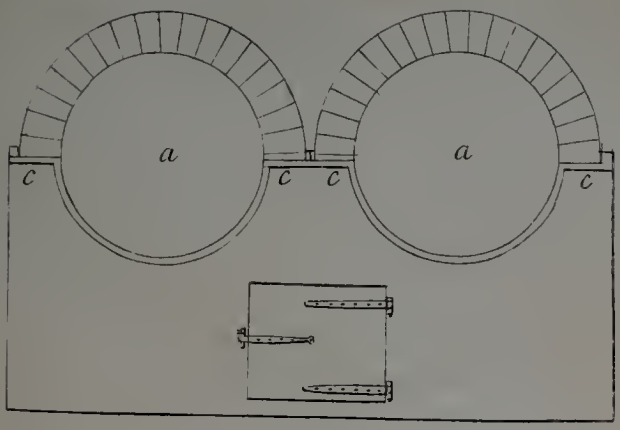
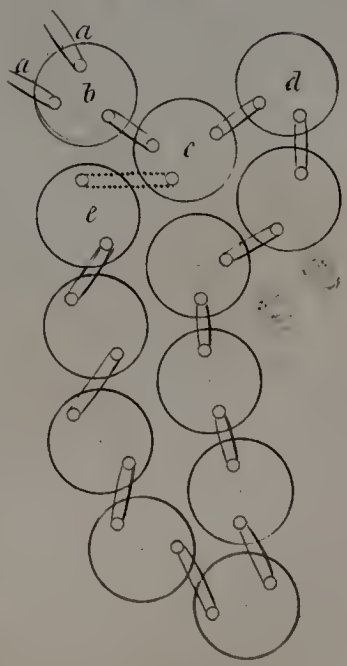



*Fig. 237.*



ceivers may be used for two cylinders, and, if the establishment be sufficiently large to employ more cylinders, it is better that each pair should be furnished with a distinct series of receivers. Five hundred and seventy pounds of coarse muriate of soda and five hundred pounds of concentrated sulphuric acid are put into each retort.—The salt is introduced first as in the distillation of nitric acid, and after the ends are cemented in, and the junctures throughout the apparatus are made secure with Roman cement, (six gallons of water being previously introduced into each of the receivers except the two first in the series) the acid, is introduced, and the heat raised suddenly to the required point. The same precaution is necessary to deposite the acid near the centre of the retort, from which point it will flow each way, as directed in the distillation of nitric acid; if this precaution be omitted, and the acid be allowed to accumulate at either end, the effervescence where the heat is applied will drive all the salt to the opposite end, and the decomposition will be liable to be incomplete. As the tubes in none of the receivers are allowed to terminate below the surface of the liquid in them, there is no occasion whatever for safety tubes in this apparatus.

During the distillation the receivers, beginning with the third, become hot, and then cool successively as the absorption progresses, and the water becomes saturated, and when the last receiver has become hot and cool again, we may infer that the process is finished.

The product from the above quantities of materials should be about 14 cwt. of acid of a specific gravity of 1.170 to 1.175. The usual commercial strength is, or should be, 1.160.

No water is put in the two first receivers, and therefore very little muriatic acid is condensed in them. They serve to condense and receive the sulphuric acid, which is volatilized during the process. There is a particular advantage in having three tubulures in the second receiver; towards the last of the distillation, the temperature is necessarily raised so high that a considerable proportion of sulphuric acid is volatilized, and more than can be condensed in the two first receivers; in this way the whole product is liable to be contaminated. To avoid this evil the receivers are so arranged that the last of the series shall approach as near to the second receiver as they do to each other generally, and towards the last of the process the communication between the second and third receivers is cut off by withdrawing the connecting tube, and closing the apertures, and the second receiver and the last of the series are connected as indicated by the dotted lines in Fig. 237. In consequence of this arrangement the last receiver, which, if the number and capacity of receivers be sufficiently large, will have become but slightly, if at all, impregnated with muriatic acid, and will absorb and condense the whole of the volatilized sulphuric acid, which would otherwise be distributed through the series and contaminate the whole product. This reversion of the order of the process is productive of no inconvenience whatever, except the trouble of withdrawing and inserting the tubes as directed; this a dexterous operator will execute with very little loss of gas or risk to himself, if the fire be allowed to burn low before the operation be attempted, and the communication with the receiver *e* be formed before that between *c* and *d* be interrupted.

At the commencement of the first distillation, where the cylinders are new the heat may be suddenly raised so high as to occasion a violent effervescence of the materials, by which means the brick portion of the cylinders becomes coated with a glazing of salt, which ensures their tightness. If a portion of the materials are driven out of the cylinder by this operation, it is of little consequence, as they must be condensed in the first receiver, and may be returned to the retort in the second operation.

Where a very concentrated acid is required, Clement's absorbing cascades (vide Fig. 107) may be employed, but a more concentrated acid than can be readily formed by the above more simple method is rarely required, and is not well adapted for keeping.

The materials remaining in the retorts after the distillation of the muriatic and nitric acids are usually disposed of by the English manufacturer in the following manner: two parts of the former and one of the latter are mixed with two parts of slaked lime, and one of slack (small coal) and thrown into a reverberatory furnace; they are melted and stirred till the flame proceeding from

them nearly ceases, and the blackness disappears, and then drawn off into moulds. This product is sold to the soap boilers, and to them only under the name of rough barilla. For another disposition of the caput mortuum after the distillation of muriatic acid, as well, indeed, as for the sal enixum, the reader is referred to the article *alum* in this work.]

## *Uses of Muriatic Acid.*

The muriatic acid is used to mix with nitric acid, in order to enable it to dissolve gold and platinum; to scour metals; to prepare muriate of tin for the dyers, to extract the phosphate of lime from bones; to mix with salt and saltpetre, to preserve flesh provisions, and several other purposes.

Theoretical chemists keep the acid highly concentrated; but for medical purposes, the spirit of salt is sold at about the specific gravity of 1,170, or so that an ounce measure may saturate 124 grains of sub-carbonate of soda, that being the strength ordered by the College. Henry, for analyses, recommends it to be kept at 1,074, so that it may saturate the same quantity of alkaline liquors, as sulphuric acid at 1,135.

Dr. Thomson has lately given the following statement of the specific gravity of muriatic acid of various strengths.

| | | | | |
|---|---|---|---|---|
| One proportion, or atom of acid, with | 6 | of water | - | 1,203 |
| | 7 | - | - | 1,179 |
| | 8 | - | - | 1,162 |
| | 9 | - | - | 1,149 |
| | 10 | - | - | 1,139 |
| | 11 | - | - | 1,1285 |
| | 12 | - | - | 1,1197 |
| | 13 | - | - | 1,1127 |
| | 14 | - | - | 1,1060 |
| | 15 | - | - | 1,1008 |
| | 16 | - | - | 1,0960 |
| | 17 | - | - | 1,0902 |
| | 18 | - | - | 1,0860 |
| | 19 | - | - | 1,0820 |
| | 20 | - | - | 1,0780 |

The composition of muriatic acid is differently stated. Berzelius, in his Proportions Chimiques, considers it as the combination of the hitherto unseparated muriatic radical, with two proportions of oxygen, or M··, and its equivalent number as 342,650. On the other hand, Gay Lussac, Sir Humphry Davy, and their followers, consider it as a hydro acid, formed of one proportion each of chlorine and hydrogen, or Cl H, and hence Thomson states the weight of the muriatic acid gas at 4,625. Water is capable of absorbing 418 times its bulk of this gas, but the most permanent combination seems to be that of sixteen proportions of water to one of muriatic acid, as it sustains the greatest heat, namely, 232° Fahrenheit, before it boils.

### OXYMURIATIC ACID.

This is the *dephlogisticated marine acid* of its discoverer, Scheele, the *oxygenated muriatic acid* of the old French nomenclature, and the *chloric acid* of the new French nomenclature. Its acid properties are but slight in some respects, although

Fig. 105.

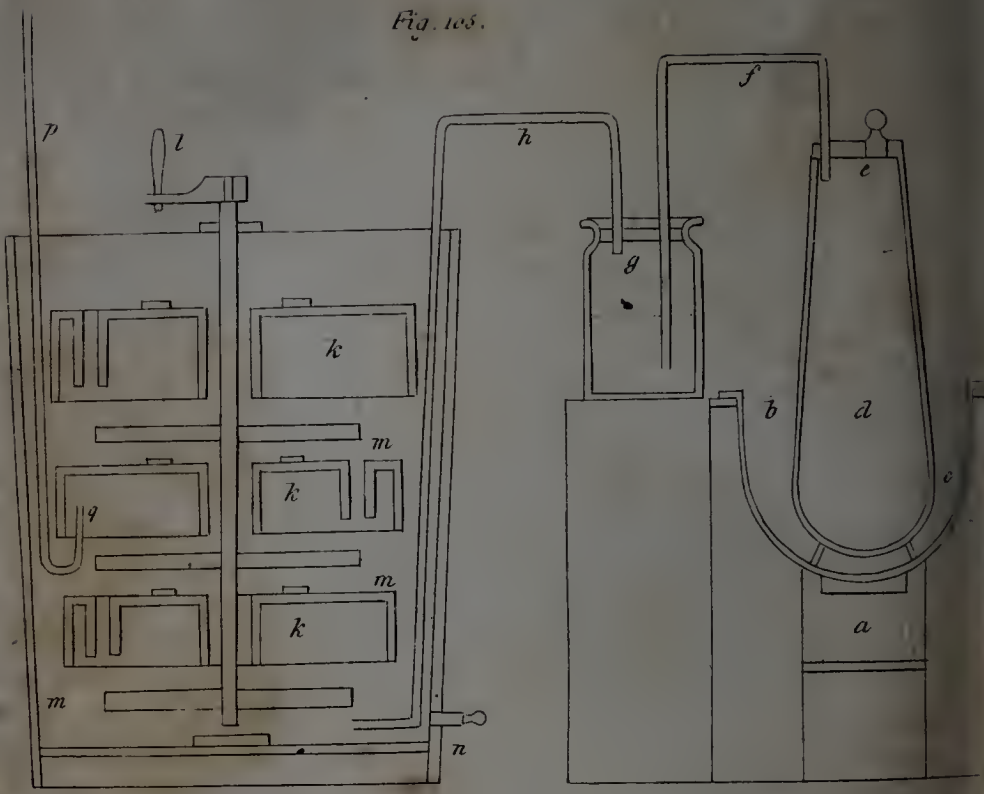
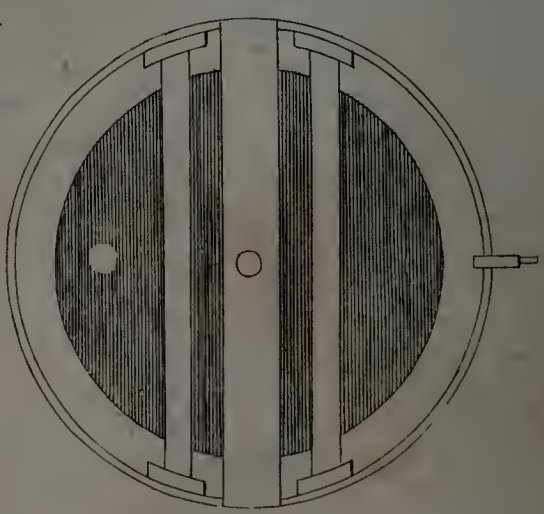



Fig. 106.



very powerful in others. It entirely destroys the blue colours of vegetables, rendering them yellowish white, even those which resist the power of other acids; hence it is used in bleaching linen and paper, and is sold under the name of *bleaching liquor*. It has also an astringent taste, instead of the usual sour taste of most acids.

Fig. 105, is the elevation of Berthollet's apparatus for preparing oxygenated muriatic acid, with some alterations, as adopted in England, in which is represented a furnace, *a*, having set in it an iron kettle, *b*, with a trivet, *c*, on which is placed a body, *d*, cast of new lead, as the acid acts powerfully on tin, and, therefore, neither old lead, sheet lead soldered, nor pewter, can be used. Some use stone-ware bodies.

The mouth, *e*, of the body, is closed by a waxed cork, or leaden stopper, with two holes, through one of which passes a leaden, pipe, *f*, which forms a communication between the inside of the body, *b*, and the intermediate stone-ware jar, *g*, where it also passes through a waxed cork, or leaden stopper, which closes the mouth of that jar: the other hole, *e*, has a plain stopper. If corks are used, they ought to be prepared beforehand, and well fitted to the mouths of the body and jar, and the holes also well adapted to the pipes, which must be luted first with fat lute, and the joints then covered with strips of linen smeared with cheese and lime lute.

The intermediate vessel, *g*, is filled about an eighth part with water, and communicates by the pipe, *h*, with the tub, *i*. This pipe reaches to the bottom of the tub, where it is bent horizontally, so that the gas may be emitted under the first of the three wooden, or, if they can be procured, stone-ware cavities, or gas receivers, *k*, which are placed in the inside of the tub, one above the other. *L*, is a handle which serves to turn the agitators, *m*, the movement of which facilitates the combination of the gas with the water; *n*, is a spigot and faucet, to draw off the liquor.

Fig. 106, represents the manner in which the gas receivers, if of wood, are kept down in the water of the tub, by means of two bars, pinned by wooden pegs to certain projections within the tub.

Each cavity, *k*, in fig. 217, is so constructed that it may receive the gas which is emitted from the pipe, *h*. The gas, as it comes out, is collected under the lowest cavity, and increases in quantity until it passes by the funnel, *o*, to that in the middle, and afterwards to the upper end. The opening through which the agitator, *l*, passes, in the centre of each cavity, is in the shape of a funnel, and is so formed as to hinder the gas from escaping along the agitator, which is furnished with three transverse arms, *n*, fastened by a wedge.

The bent tube, *p*, serves to draw off the atmospheric air which is contained under the cavities, after the tub has been filled with water. To make use of this tube, the bent part is successively introduced under each cavity, as shown at *q*. It must then be blown into, at the end, *p*, till the water in it is forced out; then, on ceasing to blow, the air contained under the cavity will immediately make its escape.

Some manufacturers conceive this apparatus as too complex for the use of a manufactory, and think that a range of four, five, or six hogsheads, or rum puncheons, connected with one another in the manner of Woulfe's distilling apparatus, is preferable to either of them. Agitators on M. Berthollet's principle, may be applied. The retort, or matrass, should be of lead, standing in a water bath: its neck should be of sufficient length to condense the common muriatic acid, which always comes over; and it should have an inclination towards the body of the retort, so that the condensed acid may return into it. The liquor

is always the strongest when the distillation is carried on very slowly; and the strength is considerably increased by diluting the vitriolic acid more than is usually done. The following proportions are said to afford the strongest liquor:—three parts of manganese; eight parts of common salt; six parts of oil of vitriol; and twelve parts of water. The proportion of manganese is subject to variation according to its quality. Manganese, which has been used for the production of oxygen, answers equally well as fresh manganese.

The absorbing and productive cascades, is an apparatus invented and employed by M. Clement, a celebrated French chemist of the present day, to promote the absorption or solution of gases, and particularly applicable to the preparation of this acid; it is known that absorption takes place in proportion to the pressure on the absorbing liquid, the extent of surface exposed to the absorbing action, and to the length of time in which it is exposed. If the pressure, however, is very great, the vessels are apt to burst, and, therefore, in general, the object chemists have had in view has been to strengthen the influence of the two other principles we have just mentioned.

Fig. 107, represents M. Clement's apparatus; *a*, *b*, is a long cylinder full of a great number of small glass or porcelain balls, about one-third of an inch in diameter. This cylinder is fixed in another of a much greater diameter, in which a hole, *c*, is made corresponding to the lower extremity of *a*, *b*, and with which two small pipes, *d*, *e*, communicate; one being intended to introduce the gas, the other to empty the liquid. A stream flows from a cistern, *f*, by means of the pipe, *g*, which has a cock, so that this stream may be regulated at pleasure. The water in its descent is detained by all the little balls, which it wets successively, and is a considerable time before it reaches the bottom: on the other hand, as the gas arises, it occupies all the empty space, is much divided and subdivided; and as it also is detained in its progress upwards, the time it is in contact with the water, is so very considerable, that the author of this invention supposes it is more than three hundred times more efficacious in promoting the absorption of a gas, than the ordinary apparatus. This he calls the absorbing cascade.

To this apparatus he connects another, which he calls the productive cascade. It is intended to produce gas for a considerable period of time, and in a more convenient and less expensive manner than by the ordinary methods. Thus, for the present purpose of preparing oxymuriatic acid, a large vessel, *h*, provided with four openings, or holes, is filled with the oxide of manganese broken into large pieces. The mouth, *i*, is connected with a leaden bottle, *k*, containing common salt and sulphuric acid. A small stream is made to flow by the tube, *l*, from the cistern, *m*, which gradually moistens the whole surface of the pieces of manganese, and permits the muriatic acid gas to attack and dissolve them very easily. The oxymuriatic acid gas which is produced, passes by the pipe, *n*, into the absorbing cascade, while the muriate of manganese is carried off as it is formed along with the water through the pipe, *o*, into the jar, *p*.

By using this apparatus there is no occasion to reduce the manganese to powder, and a much larger quantity may be operated on at the same time without the operator being under the necessity of frequently renewing the charge of materials, and dismounting his apparatus.

Oxymuriatic acid has only been used in bleaching linen and paper; but at present, the use of oxymuriate of lime, or bleaching powder, has been preferred for the former manufactory.

Each avoirdupois pound of common salt furnishes in general, oxymuriatic acid (or chlorine) gas sufficient to saturate about four pints, or half a gallon of water. The tub containing the acid should be kept covered, to prevent the day-light from changing it into common muriatic acid. It freezes at 40° Fahr. the ice being in deep yellow crystalline plates, containing more of the gas than the liquid acid, and hence when they melt, an effervescence is produced by the escape of the surplus of the gas.*

### *Oxymuriatic Acid Gas.*

This is the *chlorine gas* of the newest nomenclature, and is used for destroying the miasmata which are the cause of typhoid and remittent fevers.

For this purpose a mixture of black manganese, salt, and oil of vitriol, as for preparing bleaching liquor, is put into saucers, which are placed over chafing dishes in the rooms or churches which are to be disinfected. The rooms are shut up for a few hours, then opened and ventilated as much as possible before they are used.

M. Guyton de Morveau proposed a portable apparatus for disinfecting sick rooms, consisting of a very strong ounce and half stoppered bottle, in which is put forty-five grains of coarse powder of black manganese, and one hundred grains of nitric acid, at 17° Baumé. The stopper is kept down by the bottle being enclosed in a wooden case with a screwed top. On taking out the bottle, and loosening the stopper for a moment, until the smell of oxymuriatic acid gas is perceived, the miasmata in the neighbourhood of the bottle will be destroyed.

This gas may be collected, but cannot be preserved over water, on account of that liquid slowly absorbing it: stoppered bottles must therefore be used for that purpose.

Oxymuriatic gas is supposed to be an elementary body, by some called chlorine, which, with hydrogen, form common muriatic acid, and which combines with several proportions of oxygen: but Berzelius considers it a combination of the muriatic radical with three charges of oxygen, or M:·, calls it *muriatous super oxide*, and states its weight as 442,650.

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* The liquid oxymuriatic acid, or watery solution of chlorine, is now entirely superseded in the art of bleaching cottons and linen by the chloride of lime or bleaching powder. In the article on the manufacture of this substance by the editor, the reader will find some remarks on the foregoing apparatus of M. M. Berthollet and Clement.—Am. Ed.

### NITRO MURIATIC ACID.

The nitric and muriatic acids unite together chemically, and form compounds, varying in properties according to the proportions in which they are mixed: but which have not yet been properly investigated.

Baumé recommends two parts of nitric acid and one of muriatic acid for dissolving gold; but equal parts of the two acids for dissolving platinum; both which metals are not dissolvable in either of the acids when separate.

If the acids are both concentrated they effervesce very violently for some time after they are mixed, and much of the acids fly off.

The theory of the change in the properties of the acids by their mixture is a disputed point in chemistry.

Nitro muriatic acid is confounded, by the theoretical chemists, with aqua regis.

### ACETIC ACID.

Acetic acid is found combined with potash in the juices of a great many plants. Almost all dry vegetable substances, and some animal, subjected in close vessels to a red heat, yield it copiously. It is the result likewise of the spontaneous fermentation, to which all liquid vegetable and animal matters are liable. Strong acids, as the sulphuric and nitric, acting on vegetable matter, produce the acetic acid.

It was long supposed, on the authority of Boerhaave, that the fermentation which forms vinegar is uniformly preceded by the vinous. This is a mistake. Cabbages sour in water, making sour crout; starch, in starch makers' sour waters; and dough itself, without any previous production of wine.

If by age the wine has lost its extractive matter, it does not readily undergo the acetous fermentation. In this case, acetification, as the French term the process, may be determined, by adding slips of vines, bunches of grapes, or green woods.

It has been asserted that spirit of wine, added to fermenting liquors, does not increase the product of vinegar; but this is a mistake, for Stahl observed long ago, that if roses or lilics are moistened with spirit of wine, and placed in vessels in which they are stirred from time to time, vinegar will be formed. He also informs us, that if after abstracting the citric acid from lemon juice, by crab's eyes (a carbonate of lime,) a little spirit of wine is added to the supernatant liquid, and the mixture kept in a proper temperature, vinegar will be formed.

Chaptal says that two pounds of weak spirit of wine, sp. gr. 0.985, mixed with 300 grains of beer yeast, and a little starch water, produced extremely strong vinegar. The acid was developed on the fifth day. The same quantity of starch and yeast, without the spirit, fermented more slowly, and yielded a weaker vinegar.

### *Wine Vinegar.*

The following is the plan of making vinegar at present practised in Paris. The wine destined for vinegar is mixed in a large tun with a quantity of wine lees, and the whole being put into sacks, placed within a large iron bound vat, the liquid matter is pressed out.

What passes through is put into large casks, set upright, having a small aperture in their top. In these it is exposed to the heat of the sun in summer, or to the heat of a stove in winter.

Fermentation comes on in a few days. If the heat should then rise too high, it is lowered by cool air, and the addition of fresh wine. In summer the process is generally completed in a fortnight; in winter double the time is requisite. The vinegar is then run off into barrels, which contain several chips of beech wood to clarify it: in about a fortnight it is fit for sale.

Almost all the vinegar of the north of France being prepared at Orleans, the manufactory of that place has acquired such celebrity as to render their process worthy of a separate consideration.

The Orleans casks formerly contained nearly 200 gallons of wine, but at present only about half that quantity. Those which have been already used are preferred. They are placed in three rows one over another, and in the top have an opening of two inches diameter, which has a bung fitting close; there is another spill hole on the side to admit the air. Wine a year old is preferred for making vinegar, and is kept in adjoining casks, containing beech shavings, to which the lees adhere.

The wine thus clarified is drawn off to make vinegar. At the first setting up of a manufactory, so much good vinegar, boiling hot, is first poured into each cask, as to fill it up one-third of its height, and left there for eight days. Two gallons and a half of wine are mixed in every eight days, till the vessels are two-thirds filled. Eight days afterwards, ten gallons of vinegar are drawn off for sale, and the cask is again gradually filled. Thus each cask or *mother* yields twice its own admeasurement of vinegar in a year.

It is necessary that a third part of the cask should always be left empty.

In order to judge if the mothers work well, the vinegar makers plunge a spatula into the liquid, and if it brings up a white froth, the making of the vinegar is judged to succeed well; if red, they add more or less wine, or increase the temperature.

In summer the atmospheric heat is sufficient. In winter,

stoves heated to about 75° Fahrenheit maintain the requisite temperature in the manufactory.

The casks get filled with lees in about ten years, and require to be cleansed; and fresh casks must be mounted every twenty-five years.

If the vinegar is not clear, it is clarified by being put for some time in a cask filled with shavings of beech wood.

In some parts of France, private persons keep, in a place where the temperature is mild and equable, a vinegar cask, into which they pour such wine as they wish to change into vinegar, and it is always kept full, by replacing the vinegar, as fast as it is drawn off, by new wine.

To establish this household manufacture, it is only necessary to buy at first a small cask of good vinegar.

A slight motion is found to favour the fermentation of vinegar, and its decomposition after it is made.

Chaptal thus ascribes to agitation the operation of thunder; though it is well known that when the atmosphere is highly electrified, beer is apt to become suddenly sour, without the concussion of a thunder storm.

In cellars exposed to the vibrations occasioned by the rattling of carriages, vinegar does not keep well. The lees which had been deposited by means of isinglass and repose, are thus jumbled into the liquor, and make the fermentation re-commence.

### *The Dutch method of making Wine Vinegar is thus described by Boerhaave.*

Two large wooden vats or hogsheads are chosen, and in each of these a wooden grate or hurdle, at a distance of a foot from the bottom, is placed. The vessel is set upright, and in the grate a moderately close layer of green twigs or fresh cuttings of the vine is placed. The vessel is then filled up with the foot-stalks of grapes, commonly called the rape, to the top of the vessel, which is left quite open.

The two vessels being thus prepared, the wine to be converted into vinegar is poured in; one is filled quite up, the other but half full. They are left thus for twenty-four hours, and then the half filled vessel is made quite full from the liquor of that which was before entirely so; this, in its turn, will be only half full.

Four and twenty hours afterwards the same operation is repeated and proceeded in, the vessels being alternately kept full and half full during the twenty-four hours, till the vinegar is made.

On the second and third day, there will arise in the half filled vessel, a fermentative motion, accompanied with a sen-

sible heat, which will gradually increase from day to day. On the contrary, the fermenting motion is almost imperceptible in the full vessel; and as the two vessels are alternately full and half full, the fermentation is, by this means, in some measure interrupted, and is only renewed every other day in each vessel.

When this motion appears to have entirely ceased, even in the half filled vessel, it is a sign that the fermentation is finished; and, therefore, the vinegar is then put into casks, close stopped, and kept in a cool place.

A greater or less degree of warmth accelerates or checks this, as well as the spirituous fermentation. In France, it is finished in about fifteen days, during the summer; but if the heat of the air be very great, and exceed 25° Reaum. or 88° Fahr. the half filled vessel must be filled up every twelve hours; because, if the fermentation be not so checked in that time, it will become violent, and the liquor will be so heated, that many of the spirituous parts on which the strength of the vinegar depends, will be dissipated, so that nothing will remain after the fermentation but a vapid liquor, sour indeed, but effete.

The better to prevent the dissipation of the spirituous parts, it is a proper and usual precaution to close the mouth of the half filled vessel, in which the liquor ferments, with a cover made of oak wood. As to the full vessel, it is always left open, that the air may act freely on the liquor it contains; for it is not liable to the same inconveniences, because it ferments very slowly.

### *Malt Vinegar.*

In this country vinegar is usually made from malt. By mashing with hot water, 100 gallons of wort are extracted, in less than two hours, from six bushels of malt. When the liquor has fallen to the temperature of 75° Fahr., four gallons of yeast are added. After thirty-six hours it is racked off into casks, which are laid on their sides, and exposed, with their bung holes loosely covered, to the influence of the sun in summer; but in winter they are arranged in a room heated by stoves. In three months this vinegar is ready for the manufacture of sugar of lead.

To make vinegar for domestic use, however, the process is somewhat different. The above liquor is racked off into pairs of casks placed upright, having a false bottom pierced with holes fixed a foot from their bottoms. On this a considerable quantity of rape, or the refuse from the makers of British wine, or otherwise a quantity of low-priced raisins is laid. The liquor is pumped into the other barrel every twenty-four hours, in which time it has begun to grow warm. Sometimes, indeed,

the vinegar is fully fermented without the rape, which is added, towards the end, to communicate flavour.

Vinegar is made at Ghent, in Flanders, from beer; in which the following proportions of grain are found to be most advantageous: 1880 pounds of malted barley; 700 of wheat; and 500 of buckwheat. These grains are ground, mixed and boiled, along with twenty-seven barrels of river water, for three hours: eighteen barrels of good beer for vinegar are obtained. By a subsequent decoction, more fermentable liquid is extracted, which is mixed with the former. The whole brewing yields about 750 gallons, English measure, of vinegar.

Common vinegar has, sometimes, sulphuric acid fraudulently mixed with it, to give strength. This adulteration may be detected by the addition of a little chalk. With pure vinegar, lime forms a limpid solution; but with sulphuric acid, a white insoluble sulphate. Muriate of barytes is a still nicer test. Vinegars are allowed, by the English laws, to contain a little sulphuric acid, but the quantity is frequently exceeded.

Copper is discovered in vinegar by adding more ammonia water than is necessary to saturate it, as a fine blue colour is produced; and lead is discovered by sulphate of soda, hydrosulphurets, sulphuretted hydrogen, and gallic acid, all which throw down a sediment. None of these should produce any change on genuine vinegar.

The excise duty upon vinegar is not calculated by its own specific gravity, but by that of the solution of lime, formed by means of it, as marked by hydrometers, called acetometers. The quantity of carbonate of soda it would require to saturate it, seems a more eligible process, and would tend to discourage the addition of sulphuric acid.

### *Sugar Vinegar.*

Good vinegar may be made from a weak syrup, consisting of ten avoirdupois pounds of sugar to every eight gallons of water. The yeast and rape are to be here used as before described.

This sugar vinegar is usually flavoured with various fruits, one of those most commonly used in gooseberries; twelve pints of bruised gooseberries are generally mixed with the above proportion of sugar and water, put into stone bottles of a moderate size, stopped with a loose cork, merely to keep out the dust, and exposed to the sun, until the vinegar is completed, which generally takes a whole summer.

Whenever the vinegar is considered to be completely made, it ought to be decanted into tight barrels or bottles, and well secured from access of air. Boiling for a few minutes before it is bottled is found favourable to its preservation.

### *Distilled Vinegar.*

Vinegar, obtained by the preceding methods, has more or less of a brown colour, and a peculiar, but rather grateful, smell. By distillation in glass vessels, the colouring matter, which resides in a mucilage, is separated; but the fragrant odour is generally re-placed by a burnt or smoky smell and taste.

The best French wine vinegars, and also some from malt, contain a little alcohol, which comes over early with the watery part, and renders the first product of distillation scarcely heavier, sometimes even less heavy than water. It should accordingly be rejected.

Towards the end of the distillation, the burnt odour and taste increases. Hence, only the intermediate portions are retained as distilled vinegar. The specific gravity varies from 1.005 to 1.015, while that of common vinegar of equal strength, varies from 1.010 to 1.025.

To avoid the burnt smell and taste, the London druggists mix an equal measure of water with the vinegar before distillation, and draw off the original quantity.

### *Vinegar of Wood, or Pyroligneous Acid.*

Vinegar has been long prepared for the calico printers, by subjecting wood in iron retorts to a strong heat. The following arrangement of apparatus has been found to answer well. A series of cast-iron cylinders about four feet diameter, and six feet long, are set in pairs horizontally in brickwork, so that the flame of one fire may play round both. Both ends project a little from the brick-work. One of them has a cast-iron plate well fitted and firmly bolted to it, from the centre of which an iron pipe about six inches diameter proceeds, and enters at a right angle the main cooling pipe. The diameter of this main pipe may be from 9 to 14 inches, according to the number of cylinders. The other end of the cylinder is called the mouth of the retort. This is closed by an iron plate smeared round its edge with clay, and secured in its place by wedges. The charge of wood for such cylinder is about 8 cwt.

The hard woods, oak, ash, birch, and beech, are alone used, but fir does not answer. The heat is kept up during the day time, and the furnace is allowed to cool during the night. Next morning the door is opened, the charcoal removed, and a new charge of wood is introduced. The average product of wood vinegar, or raw pyroligneous acid, is thirty-five gallons. It is much contaminated with tar; is of a deep brown colour; and has a sp. gr. of 1·025, so that it weighs about 3 cwt.; but the residuary charcoal is found to weigh no more than one-fifth of the wood employed.

The raw pyroligneous acid is rectified by a second distilla-

tion in a copper still, in the body of which about twenty gallons of viscid tarry matter are left from every hundred of vinegar, and there passes over a transparent, but brown vinegar, having a considerable burnt smell, and its sp. gr. is 1·013. Its acid powers are superior to those of the best wine, or malt vinegar, in the proportion of three to two.

The French now manufacture wood vinegar in a different apparatus, in which the gas yielded by the wood is made to supply a part of the heat necessary for its own distillation.

Fig. 108, represents this apparatus. Wood, well seasoned and dried, is introduced into a large upright cylinder, *a*, made of iron plates rivetted together, and having on the side of its upper part a short cylindrical neck. An iron cover, *b*, is closely fitted to this pot, and then it is lifted by means of a crane and tackle, *c*, and placed in the furnace, *d*, of the same shape as the pot, and the furnace is then covered with a lid, *e*, constructed of brick work. A moderate heat is then applied to the furnace, at first the vapour soon ceases to be transparent, and smoke begins to issue. At this time two adapters are fitted to the cylindrical neck, by whose means the cylinder serving as a body, is connected with the condensing apparatus. This apparatus is different in the various manufactories; in some the condensation is effected by the coolness of the atmosphere, the vapours being made to pass through a long extent of cylinders, and sometimes of casks adapted to each other, but most generally, the condensation or cooling is effected by water, when it can be procured in sufficient quantities.

The most simple apparatus for this purpose consists of two cylinders, *e*, *f*, enclosed one within the other, and having between them a space sufficient to allow a large quantity of water to flow through them, and thus cool the vapour. These cylinders are adapted to the distilling apparatus, and placed inclined to the horizon. To the first double tube, a second, and then a third, is adapted, and placed in a zigzag form, in order to occupy as little space as possible. The water is made to circulate in the following manner: at the lower extremity, *g*, of the condensing apparatus, there is a pipe which ought to be somewhat higher than the highest part of the whole of the condensing apparatus, where, at *h*, there is another pipe bending down towards the ground. The water from a cistern runs through the perpendicular pipe, *g*, to the lower part of the condensing apparatus, and fills all the space between the cylinders, *e*, *f*. When the operation is going on, as the vapours are condensed, they raise the temperature of the water, which becoming more rarified and lighter, ascend to the highest point, and flow out of the curved pipe, *h*, and are replaced by fresh cold water from the cistern.

The condensing apparatus terminates in a brick gutter, *i*, which is constructed under ground. At the end of this gutter is a bent pipe, *K*, which allows the liquid products to flow into a cistern, from whence, when it is full, it discharges itself by means of a syphon into a large reservoir. The pipe which is at the end of the gutter dips into the liquid, and thus cuts off the communication with the interior of the apparatus. The gas, which is disengaging, is conveyed by means of the tube, *i*, *l*, from one of the sides of the gutter, *i*, below the ash-room. This pipe has a cock, *m*, before reaching the furnace, in order to regulate the quantity of gas that may pass, and to cut off the communication at pleasure. That part of the pipe which ends in the ash-room of the furnace, rises perpendicularly some inches, and terminates at *n*, like the nose of a watering pot: by this means the gas is distributed equally under the distilling vessel, without any risk of the pipe being obstructed either by the fuel or the cinders.

[This last-mentioned French apparatus is too refined and complicated for a manufactory of this article on an extensive scale; the condensing part is particularly so; it is a far simpler

Fig. 107.

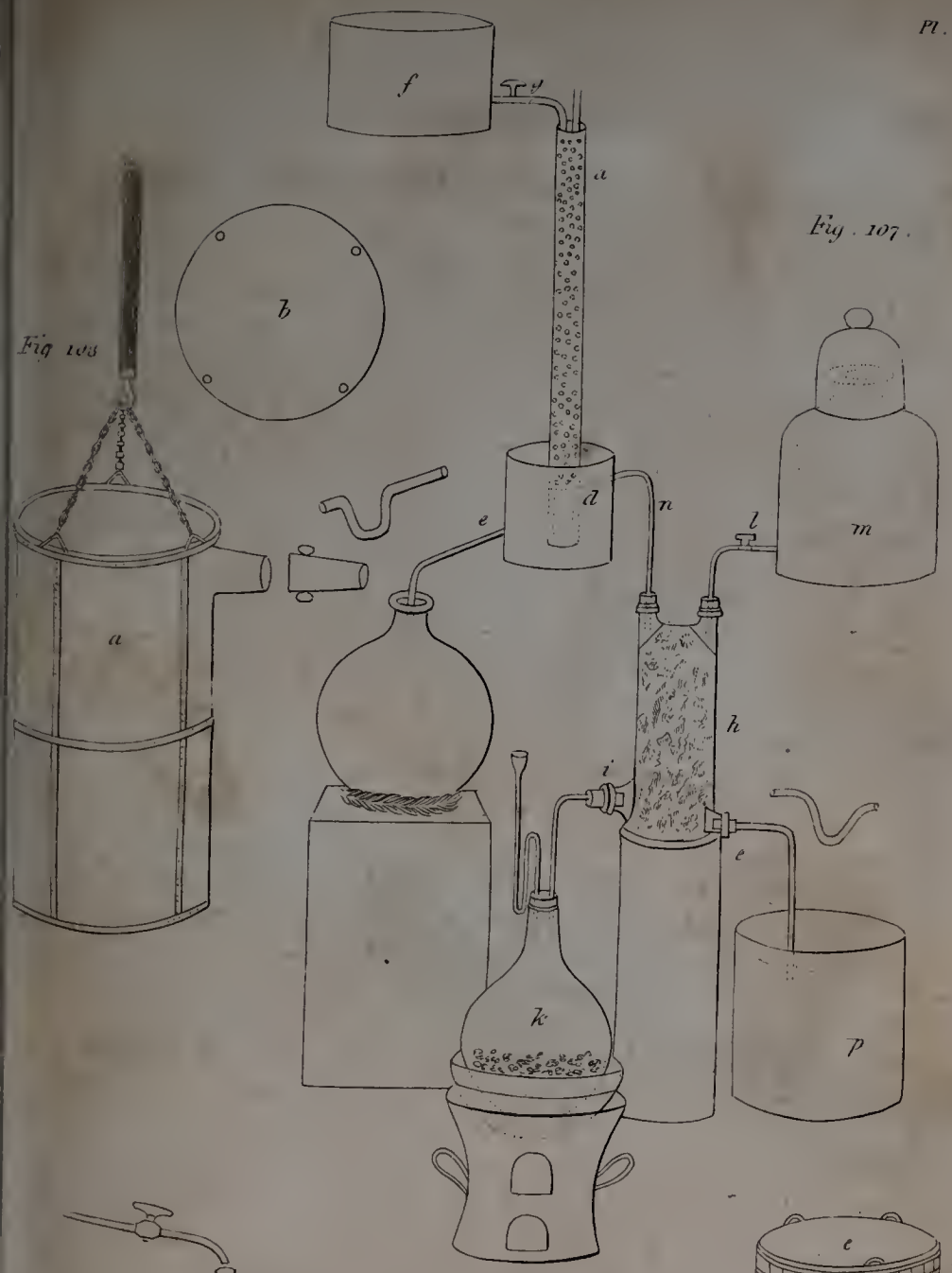
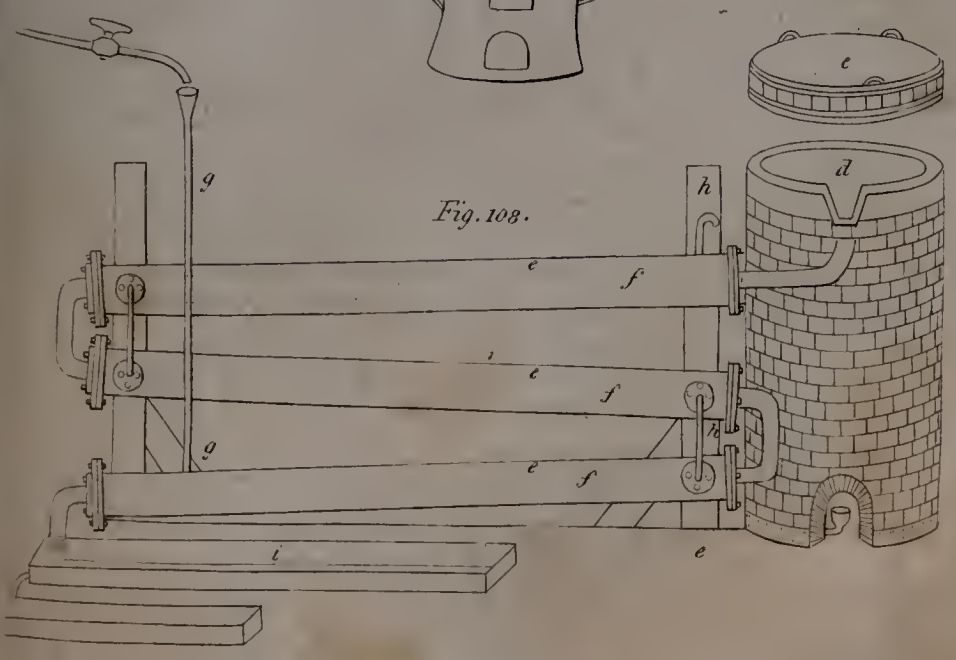



Fig. 108.



and cheaper plan to conduct the tubes through a cistern or refrigerator of cold water. The horizontal cylinder is the best form for the retort. The combustion of the gas is attended with a considerable saving in fuel. I am informed by a manufacturer of this article, that in certain stages of the distillation, it will nearly supersede the use of any other fuel. This arrangement is equally applicable to the horizontal cylinder. The cistern for the reception of the condensed acid should be very large, so as to allow time for the tar to rise before it is drawn off by the syphon, which should take the liquor from about midway from the top to the bottom of the cistern, as a portion of the impurities of the liquid fall to the bottom as well as rise to the surface. Some manufacturers employ a succession of cisterns on different levels, the highest being the first recipient, and draw from one to another so as to allow more time for the tar to rise before the acid is put into casks for the market. The greatest demand for the acid is for the uses of the calico-printers, for whom it should have a specific gravity of 1.035 or 7° on Twedale's hydrometer.]

The heat required is not very considerable, but towards the end of the operation the heat is increased, so as to make the iron cylinders red hot, and the time when the operation is completed is ascertained by the colour of the gas flame. At first it is of a reddish yellow, then it becomes blue, and finally it is quite white, which is a mark that the combustion is carried far enough. There is another mode in which the operator judges of the completion of the process: a few drops of water are let fall on that part of the pipe close to the furnace, which is not surrounded by the second pipe containing water, and when it evaporates without noise the distillation is thought to be finished. The adapting pipes are then separated, and the end of the distilling cylinder is closely stopped by an iron cover, and brick clay. The lid of the furnace is then lifted off, and afterwards the distilling cylinder is taken out and immediately replaced by another which has been prepared in the meantime. When the pot which has been taken out is cold, the charcoal is taken out and the acid is then purified.

A demidecastere of wood (two-thirds of a cubic fathom,) which requires about eight hours' firing, yields about seven voies and a half of charcoal, of about 130 pounds each: and, according to Mollerat, a cubic yard, or about 700 pounds, of wood, yield by distillation 25 gallons of pyroligneous acid, and about 50 to 60 pounds of tar.

### *Purified Wood Vinegar.*

This is also called *crystal vinegar, acidum aceticum fortius;* and *pure pyroligneous acid.*

Acetate of soda, made from rectified pyroligneous acid, and

reduced to the state of very white crystals, is ground and put into a copper pan, and there is added at once a sufficient quantity of oil of vitriol to decompose the acetate by uniting with the soda. The sulphuric acid runs to the bottom of the copper pan, the heat consequent to its action on the acetate is spread on a large mass, and does not rise very high. As the acetate falls in the middle, the laborant rakes down more, and the decomposition thus proceeds as slowly as may be desired. If the oil of vitriol is added gradually, the heat becomes considerable, so as to cause the acetic acid to rise in vapours, which are insupportable by any workmen.

Such part of the new-formed sulphate of soda as separates in crystals is separated by straining off the liquid, which is then distilled in a copper still, observing to reserve apart the latter portions of distilled liquid, as being coloured.

[Another method of procuring a very pure and concentrated vinegar, is, to saturate the redistilled pyroligneous acid with chalk, evaporate the liquid acetate to dryness, and subject it to gentle torrefaction, by which means the tarry and empyreumatic matter is completely dissipated; so that on decomposing the calcareous salt by sulphuric acid, a very pure, colourless, and grateful vinegar rises in distillation. Its strength will be proportioned to the concentration of the decomposing acid. The most difficult part of this operation is to determine the exact point at which the torrefaction is to be stopped; if it be carried too far, the acetic acid will be liable to be decomposed: if not far enough; the empyreumatic matter will not be destroyed; but a little experience will enable the operator to ascertain the necessary points.]

The acid thus obtained is generally sold in France, forty acidimetric degrees strong.

The purified wood vinegar, sold in England for pickling, and other household uses, contains about one-twentieth of its weight of pure acetic acid, and the remainder is water.

The college orders the wood vinegar used by the apothecaries, under the college name of acidum aceticum fortius, to have the specific gravity, 1,046, and that 100 grains should saturate 87 of carbonate of soda, or, in the college language, sodæ subcarbonas.

Notwithstanding Glauber wrote an express treatise upon the usefulness of wood vinegar, yet the general neglect in England of reverberatory furnaces, for distilling with a naked fire, caused his observations to be disregarded. The introduction of iron cylinders for distilling coal gas, led to the general use of Boerhaave's reverberatory furnace, and the manufacture of wood vinegar, by means of which not only the acetates of iron, and of alumine, but also the acetate or sugar of lead, are now manufactured at home, instead of being imported from Holland.

### *Spirit of Verdigris.*

This is also called *radical vinegar*, and is prepared from the distilled verdigris made in wine countries. For this purpose this crystalized acetate of copper, being slightly dried and bruised, is put into a coated glass or stone-ware retort, which may be quite filled up to the bend of the neck. To this retort is to be luted a glass adapter, and at least two or three receivers, to the last of which should be added a bent balled pipe, the farthest end of which dips into a bottle of distilled vinegar.

The apparatus being luted, the receivers being previously placed in vessels of cold water, the distillation may be begun, the heat being augmented gradually until the acid comes over in a string of drops. The vapours give out much heat to the receivers, which causes a necessity of using so many; and when the water in which they are placed grows hot, fresh cold water must be gradually added, and on no account suffered to run on the uncovered part of the receivers, otherwise they would be cracked. The heat is governed by the bubbling of the gas through the distilled vinegar, which ought not to be too quick. At first a colourless liquid comes over, then small pale green crystals appear near the end of the neck of the retort; these afterwards disappear, and colour the liquid collected in the receivers. The operation is finished when the receivers grow cool, and gas no longer passes through the distilled vinegar.

The apparatus must not be undone until the retort is quite cold, as the residuum would take fire if exposed while warm to the air. This residuum, melted with an equal weight of black flux, yields very pure copper.

Twenty kilogrammes ·315, or about 45 avoirdupois pounds of distilled verdigris, yielded nine kilogrammes ·943 of unrectified green acid, 6 kilogrammes ·792 of copper, and 3 kilogrammes ·580 of gas carried off, containing as much acetic acid as saturated ·091 of a kilogramme of very strong potasse water. The green spirit is rectified by distilling it nearly to dryness in a glass retort, changing the receiver when about one-third, being the weakest portion, has come over: the remainder is a very strong acetic acid.

As the acetic acid obtained by this process contains some of the burning spirit of vinegar, of the old chemists, or the pyro-acetic spirit of Chenevix, its smell is very agreeable, and much superior to that of the acetic acid from the alkaline acetates by sulphuric acid: so that it is used as a stimulant in smelling-bottles.

### *Spirit of Sugar of Lead.*

This, like the preceding, can only be properly made from the salt manufactured in wine countries; as the spirit distilled from

either verdigris or sugar of lead manufactured with pyroligneous acid would want that fine smell that is communicated by the pyroacetic spirit, although, when scented with oil of rosemary, or some other strong-scented oil, it will do well enough for the dull organs of scent of the Northern Europeans.

It is obtained from sugar of lead in the same manner as the spirit of verdigris is from distilled verdigris. Wilson, in 1660, added bole to prevent the salt from becoming liquid.

### *Acetic Acid by Charcoal.*

This process was invented by Lowitz. Distilled or even common vinegar is made into a paste with well-burned charcoal powder; and the paste being put into a stone-ware retort, is distilled by a gradual fire. Slightly acidulated water comes over at first, and then the receiving bottle being emptied, the joints well luted, and the heat increased, the acid comes over in a concentrated state, and may be obtained in a glacial or crystalline state.

### *Crystallized Acetic Acid, from Acetate of Soda.*

For experimental purposes dry acetate of soda and sulphuric acid are mixed in the requisite proportions and distilled in a retort: an acetic acid comes over which is so strong that it crystallizes when cooled down to a low temperature, and remains in crystals till the heat rises to 50°. By pouring the liquid portion off the crystals, and drying them on blotting paper, they may be obtained as dry as the crystals of tartaric acid.

These crystals may be melted, by leaving them for 24 hours in a warm room, into a liquid which does not crystallize, though kept for a long time in a temperature as low as 40°; but if it is even raised to the temperature of 45°, and a single crystal of acetic acid flung into it, a number of crystalline spiculæ dart out with rapidity all over the liquid, the temperature rises from 45° to 51°, and by degrees the whole liquid assumes the solid form, and is composed, according to Dr. Thomson, of one atom or charge of acetic acid united with one of water.

By dissolving given weights of the crystals of pure acetic acid in water, and examining their specific gravity at 60°, that professor found that an atom of acid, united with different numbers of atoms of water, had the undernoted specific gravities:—

| *Atoms of water.* | *Specific gravity.* |
|---|---|
| 1 | 1·06296 |
| 2 | 1·07060 |
| 3 | 1·07084 |
| 4 | 1·07134 |
| 5 | 1·06320 |
| 6 | 1·06708 |
| 7 | 1·06349 |
| 8 | 1·05974 |
| 9 | 1·05794 |
| 10 | 1·05439 |

Dr. Thomson remarks, that the specific gravity of the liquid is at a maximum when it consists of one atom of acid united to four atoms of water, and of course it follows that knowing the specific gravity of acetic acid is not sufficient to determine its strength.

100 acetic acid is composed, according to Berzelius, of 47 of carbone, 46·79 of oxygen, and 6·21 of hydrogen, or $H^6 C^4 O^3$, and its number is 641·120: Dr. Thomson corrects Berzelius' deductions, and makes the acid equal to $C_4 O^3 H^2$, or 6,250.

## BORACIC ACID,

Originally known by the medical name of *Homberg's sedative salt of vitriol*, or by contraction, of *sedative salt* only.

The easiest method of procuring boracic acid is by dissolving borax in hot water, filtering the solution, then adding sulphuric acid by little and little, till the liquid has a sensibly acid taste; and laying it aside to cool. A great number of small laminated crystals will form, which are the boracic acid. They are to be washed with cold water and drained upon brown paper. To extract the whole of the boracic acid, the solution should be evaporated after the first crop of crystals are obtained. When concentrated and set aside, an additional quantity of boracic acid falls down.

Boracic acid, thus procured, is in the form of thin hexagonal scales; of a silvery whiteness, having some resemblance to spermaceti, and the same kind of greasy feel, owing most probably to the remains of the acid employed in procuring it; and is but little used, for soldering metals.

Boracic acid has lately been found native, in Italy, in large quantities, both in a solid state, and forming an ingredient in the water of some lakes; and this has been brought into the market in such quantities, and at so low a price, that it has been used to make borax, by being united with soda.

According to Berzelius, dry boracic acid is $B^{\cdot\cdot}$, or 269,650; and the crystals, $B^{\cdot\cdot} + 2(H{\cdot}H,)$ or 496,180; but Dr. Thomson makes the atomic weight 5,250.

## CARBONIC ACID.

Scarcely any substance has had more names given it by theorists. It has been called *gas of wine*, *choke damp*, *cretaceous air*, *acidulous gas*, *aerial acid*, and by the present theorists *carbonic acid gas*, to which is usually added, in popular works, the name of *fixed air*, as an explanatory synonyme.

It is met with in the bottoms of mines left unworked, in old dried up wells, in cellars, or in pits which have not been opened for some time, and in brewers' and distillers' working tuns, on the surface of the liquor. Its presence is shown by its instantly drowning men and animals that, deceived by its being invisible; venture into it, by instantly extinguishing the flame of a candle; and by the smoke of a newly-blown out candle floating upon it as oil on water.

Carbonic acid gas, or fixed air, may be made by dissolving limestone in weak sulphuric or muriatic acid, and receiving the gas in bottles or jars in a water trough. It has been proposed

to fill up bottles with it, in order to preserve fruit, and even animal flesh, but they contract a musty flavour in it.

Carbonic acid gas is considered by the Lavoisierian theorists as C:, hence Berzelius makes its weight, 275,330; which Thomson corrects to 2,750: the Stahlians would regard it as C Aq$^{16}$ O; or three by weight of the carbonaceous element with eight of water, and an indeterminable quantity of that principle that forms oxygen gas with water.

### *Carbonic Acid Water.*

This acidulous drink has been known for some time by the name of *water impregnated with fixed air.*

When it first came into use, a number of apparatus were contrived for the speedy impregnation of the water; some of which are still in being, although seldom used, as the manufacturers supply a better article than can be made by private persons, and at a very cheap rate.

When a person lives near a brewery or distillery, a small quantity of carbonic acid water may be made occasionally by holding a flat dish of newly-boiled water a little above the surface of the liquor fermenting in the working tun; the water quickly absorbs its own measure of the carbonic acid gas or choke damp that is discharged from the fermenting liquid.

Carbonic acid water may also be made by putting pieces of marble or limestone into a retort, or gas bottle, adding very weak sulphuric acid, and receiving the carbonic acid in bottles, standing in the water-trough till they are half full; then shaking the bottles to promote the absorption of the gas. Or the water may be put into the receivers of Hassenfratz's distilling apparatus, p. 200, fig. 85, or any similar apparatus: and the gas ejected from marble or limestone sent through it.

Welter has proposed a very ingenious apparatus, which is not only applicable to the making of carbonic acid water, but also to the preparation of the super carbonates of the alkalies, and many other operations.

This apparatus is represented in fig. 109. The vessel, *e*, provided with three openings, one below and two above, is filled with marble broken into pieces. Bent pipes, 1, 2, 3, are luted to these openings. 1, is to carry the carbonic acid gas to the bottom of a tub or wide stone jar, *a*, filled with the water or other liquid to be impregnated. 2, is to convey the muriatic acid to the marble by a fine opening at the end; 3, is bent, and placed so as to carry off the solution of lime in the muriatic acid as soon as it reaches a certain height, and let it drip into the basin, *k*.

*A*, *b*, *c*, *h*, is the tub, or stone jar, for holding the water or liquid to be impregnated, and is nearly similar to that of M. Berthollet, for procuring oxymuriatic acid, but without the agitators, although these might be used. Muriatic acid, weakened with an equal quantity of water, is first poured into the bent pipe, 2, from whence it flows into *e*, and immediately disengages a portion of the carbonic acid gas from the marble, which passes into the inverted dishes, *b*, *c*; when this gas ceases to be absorbed, the muriatic acid ceases also to pass over, and stands

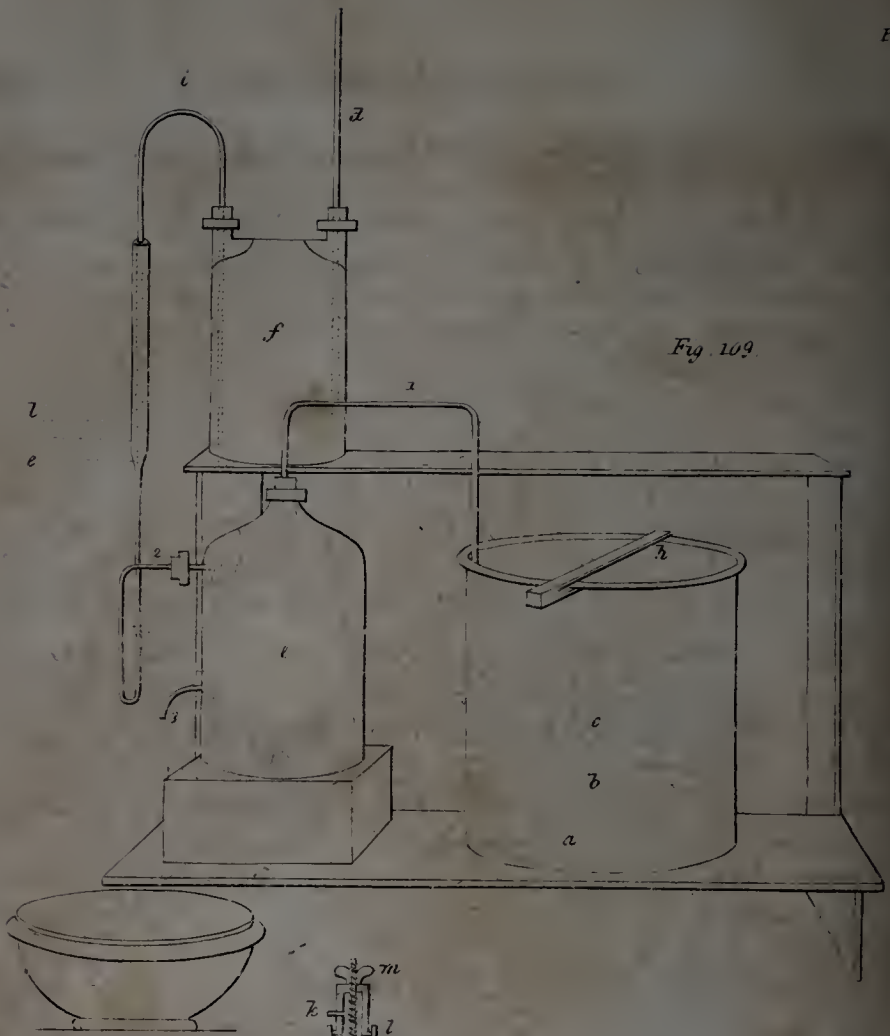



Fig. 109.

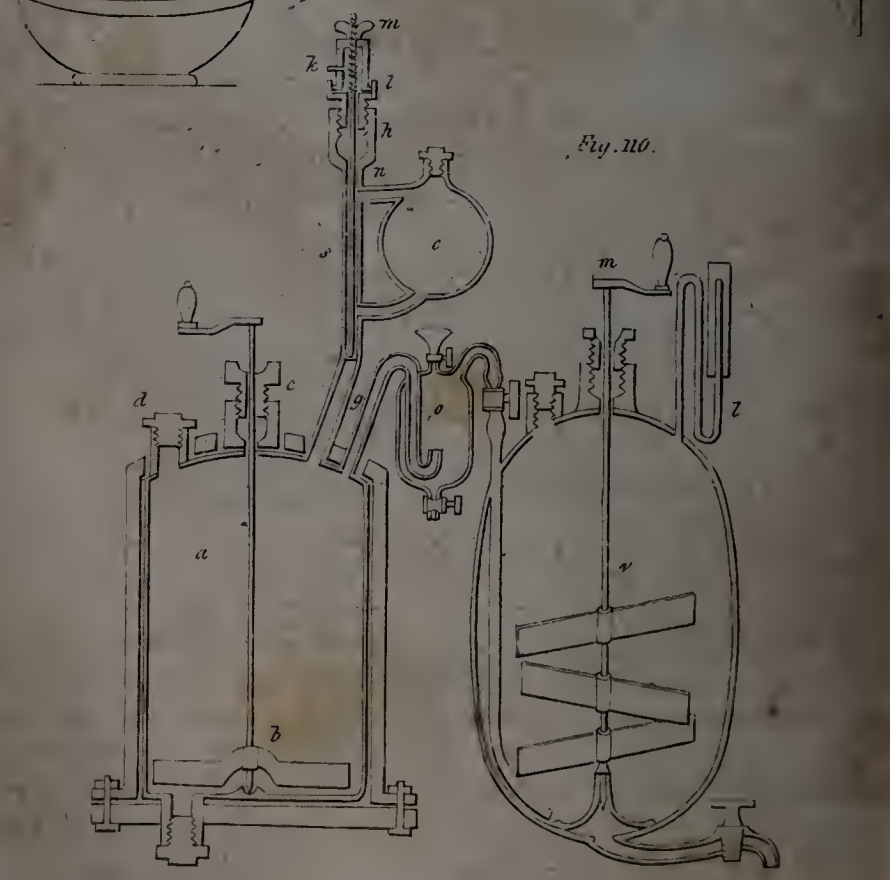



Fig. 110.

at a certain height in the bent pipe, 2, proportioned to the pressure of the water on the opening at *a*, say at *l*.

Now, in order to feed this apparatus with muriatic acid, as the water in the tub absorbs the carbonic acid gas, *f*, is a bottle with two openings, or a single wide mouth closed with a bung, with two openings. Into one of these openings, a straight cane, *d*, is luted, and into the other a simple syphon, *i*, after the bottle has been nearly filled with weak muriatic acid. The leg of the syphon, *i*, is introduced into the pipe, 2. The lower end of the cane, *d*, ought to be lower than the level, *l*, of the liquid in 2, and higher than the lowest end, *c*, of the syphon. On blowing into the cane, *d*, the muriatic acid is forced over the arch of the syphon, and flows into the pipe, 2. As the water in the tub, *a*, absorbs the gas, the muriatic acid running into the vessel, *e*, by the bent pipe, 2, brings over more muriatic acid from *f*, and when the acid in this pipe, 2, falls below the level of the lower end of *d*, as at *m*, a bubble of air passes by this pipe, and a similar quantity of acid runs through the syphon, and again from the bent pipe, 2, upon the marble in *e*, according as the carbonic acid is absorbed by the water in the tub.

This apparatus is said to work very regularly, and is certainly a useful method for causing the absorption of gases, as it continues to act till the materials are exhausted, or saturated. If the tub, or stone jar, *a*, *h*, is covered, and a cock fitted at the bottom, fresh water may be added as the already impregnated water is drawn off for use. The nature of the apparatus, however, does not allow a great pressure to be given to the gas, and hence, the water does not absorb much more than its own measure of carbonic acid gas.

But when it is required to impregnate the water with a greater quantity of carbonic acid, an apparatus must be used which will allow of considerable resistance being made to the the escape of the gas; and by this means each measure of water may be made to absorb about two measures and a half of the carbonic acid gas.

Fig. 110, represents an apparatus designed to impregnate water, with carbonic acid gas, formerly called fixed air; it is composed of the following parts.

The generator, *a*, is made of cast-iron, three quarters of an inch thick; and to prevent the sulphuric acid from acting upon it, the whole is lined with sheet lead, of about nine pounds to the square foot. This vessel contains about fifteen gallons, and has a stirrer, *b*, also lined with sheet lead, and which works on a pivot at the bottom: this pivot passing through the stuffing box, *c*, at the top of the vessel.

The vessel is filled up to the dotted line with a mixture of whiting and water, which is introduced by the opening at *d*.

The acid holder, *e*, contains two gallons, and is filled with oil of vitriol up to the dotted line. This acid holder is formed of lead, three quarters of an inch thick.

The acid is kept from running down into the generator by means of the conical lead plug, *f*, which fits into a conical opening in the leaden pipe, *g*. This plug is attached to a rod, which moves up and down through the stuffing box, *h*. As it is desirable to prevent the plug from friction, and merely to lift it out of the opening, *g*, or push it into the opening, the rod of the plug is prevented from turning round by means of a pin, *k*, moving in a slit of the bridle, *l*, and the screw nut, *m*, is rivetted loose into the top of the bridle. This kind of plug cock is more complicated than the common cock, but that would not answer where a great resistance to escape is necessary.

The pipe, *n*, which forms a communication between the top of the acid holder, *e*, and the pipe, *s*, in which the plug rod moves, preserves an equilibrium

of pressure, so as to prevent the acid from rising higher in the pipe, *s*, than the level of the acid in the acid holder: by which means, the brass work of the stuffing box is preserved from injury.

To prevent any of the sulphuric acid from being carried over by the effervescence, an intermediate vessel, *o*, containing about three gallons, is formed either of thick sheet lead, or of cast-iron, lined with lead. This intermediate vessel is filled with water up to the dotted line.

The impregnator, *v*, should contain about sixteen gallons. As to its materials, it may be made either of copper, tinned, or of cast-iron, lined with thin sheet lead; and the mill, may either be of tinned copper or of maple wood, which last, giving no taste to the water, is, perhaps, preferable. This impregnator is filled up to the dotted line with water, to which, in making saline waters, the proper proportion of sesqui-carbonate of soda, carbonate of magnesia, or other ingredient, *m*, is to be added.

A pressure gauge, *t*, of quicksilver, is to be placed at a little distance, and connected by means of a leaden pipe: but in the annexed figure, it is represented, for the sake of room, as placed on the top of the vessel.

Nothing can be more simple than the operation of this apparatus. The nut, *m*, being turned, the plug is raised, the oil of vitriol is allowed to run down into the generator, *a*, where it acts upon the whiting, and disengages the carbonic acid gas, in proportion to the quantity of the oil of vitriol that is allowed to run down at once. The nut, *m*, being turned the other way, lowers the plug, and thus stopping the descent of the sulphuric acid, the disengagement of the gas is regulated, and too great an effervescence is prevented. The gas that is disengaged passes through the intermediate vessel, into the impregnator, *v*, where it is absorbed by the water.

The water thus impregnated with the carbonic acid gas in close vessels, which offer great resistance to its escape, is then drawn off into strong half-pint bottles, by means of a cock, which descends to the bottom of the bottle, and immediately corked, and either wired, or the corks tied down.

Some persons use mechanical means to force the carbonic acid gas into water, by means of a transferring pump, or syringe, which is connected at one end with the bladder, or other reservoir of the gas; and at the other with a vessel, or single bottle of water. When the pump is worked, the gas is extracted from the bladder, transferred and forced into the water.

## FLUORIC ACID.

The fluor acid is procured from a saline stone, known by the name of fusible spar, fluor spar, false amethyst, &c. It was confounded with spar, till the miners, in consequence of their practice, distinguished it by its useful property of serving as a flux to the most refractory ores.

Marggraf was the first who examined fusible spar, and selenitic spar. He determined their different characters, and that an earthy sublimate may yield in distilling this spar with oil of vitriol.

Priestley first observed, that an acid gas was disengaged in the distillation of this spar with sulphuric acid, which communicated to water, as soon as it came into contact with it, a strong acidity, and covered the surface of the water with a stony crust.

Scheele, in 1771, assigned it the rank it was entitled to among the mineral acids.

When the fluor acid is obtained from a mixture of fluor spar and sulphuric acid in a glass retort, it is rendered impure; for it is saturated with the silica it has dissolved from the retort, and it is mixed with sulphuric and sulphurous acids. The presence of these is immediately shown by the acetate of barytes. To obtain the pure fluor acid, the mixture must be distilled in lead or tin vessels, and the inside of the receiver lined with a coat of wax.

The distillation of a mixture of four ounces of fluor spar, and twelve ounces of sulphuric acid, in this way, is sufficient to render eight ounces of water very strongly acid. The acetate of barytes does not then discover any mixture of sulphuric acid, though the acid obtained by the distillation is strong enough to dissolve calcareous earth with effervescence.

This acid must be kept in flint-glass bottles, coated internally with a mixture of wax and oil.

The acid, when obtained this way, is, however, not quite pure. It is mixed with a small quantity of oxide of lead or of tin, according to the retort made use of.

Two ounces of vitriolic acid, and half an ounce of fluor spar, were distilled in a small retort of lead, in a water bath. The retort weighed eleven ounces eight drams. In the first distillation, it lost one dram and a half; in the second, one dram: and in the third, fifty-eight grains. The acid obtained was whitish, and had a strong smell of liver of sulphur. The fluor acid alone cannot dissolve tin or lead; but during the distillation, the superabundant sulphuric acid dissolve the metal, which is taken from it by the fluor acids, and deprived of its oxygen. In this distillation, the heat of boiling water must not be exceeded, because the sulphuric and sulphurous acids would, in that case, pass into the receiver with the fluor acid.

The quality which the fluoric acid possesses of dissolving glass, and those silicious stones which resist the action of most solvents, is applicable to use.

M. Puymaurin put a small piece of diamond into the fluor acid, in a glass vessel, and heated the vessel two or three times in a sand heat; after the diamond had been four or five days in the acid it disappeared, and nothing could be observed in its place but some small shining particles, which rolled about at the bottom of the vessel, if it was at all agitated.

This experiment was repeated upon two other diamonds. These two did not appear to suffer the smallest alteration. If this experiment had not been repeated, it might have been supposed that the fluor acid was a solvent for diamonds.

M. Puymaurin also exposed various gems, and other silicious substances to the action of this acid.

It is by no means indifferent in what vessels the pieces of stone or gems to be examined are placed. The glass vessels M. Puymaurin first made use of were not so proper for the purpose as he wished. The internal surface of the vessels was corroded, a gray gelatinous substance covered the pieces of stone, and they were found little or not at all acted upon by the acid.

Vessels of box wood, although varnished, could not resist the gentle heat necessary to hasten the action of the acid; it soon penetrated through the pores in such a manner that it was necessary to procure vessels of another kind.

Vessels of pewter have all the advantages wished; but heat must be applied very gradually, because the acid becomes volatile with a very gentle heat, and the vessels, when empty, are apt to melt. It is also necessary to be very particular respecting the purity of the fluor acid; if it is mixed with sulphuric acid, this last attacks and calcines the metal of the vessels, and the fluor acid then exerts its action upon these calces or oxides, and becomes loaded with them.

M. Puymaurin exposed among several others, the following substances in pewter vessels, with a sufficient quantity of fluor acid to cover them, to a moderate heat, for the space of two days.

| | Weight in grain. | Loss of weight. |
|---|---|---|
| The kind of jaspar called blood-stone, | 8½ | 1½ |
| Striped agate, . . | 6 | 1 |
| True aventurine, but of inferior quality, | 4½ | 1½ |

The striped agate lost its transparency and its fine red colour.

The aventurine appeared only like a piece of a gray pebble, and its brilliant particles had entirely disappeared.

The blood-stone suffered the greatest change: the beautiful broad red spots, from which it takes its name, were changed into spots of a brownish red colour; the dark green was changed into a grayish colour, and the hardness of the stone was so diminished that it might be scraped with a knife. It had also become very brittle; when broke, the broken part appeared of a dark brownish green colour.

Since he made these experiments, M. Puymaurin has engraved various characters upon blood-stone, and upon agate, by means of the fluor acid.

A small hexaedral crystal lost its polish, but did not decrease

in weight. Four small garnets lost a portion of their weight, and became of a beautiful dark rose colour; the outer surfaee having been taken off by the acid. Gypsum from Montmartre, and sand-stone from Fontainbleau, were completely dissolved.

A large series of experiments have been also made by Mr. Kortum.

Fluor aeid aets more readily upon glass than upon rock-erystal. The silicious earth in glass is divided by fusion, and by its mixture with alkaline substances; and, eonsequently, presents a multitude of surfaees to the action of the aeid, whieh soon destroys it; reducing it into a light powder, of a shining white colour, and whieh may be again fused by being mixed with an alkali.

The fluor acid has almost as much action upon glass as aqua fortis and other acids have upon eopper, or other metals: and it has been applied to the engraving upon plates of glass. Although pewter or molten lead vessels may be used, yet it will be found advantageous to use a small silver alembie, holding about a pint, and receiving bottle for the distillation: two ounees of the spar, with four ounees of oil of vitriol, will yield about an ounee of very strong fluorie acid, requiring the admixture of three or four ounees of water to render it proper for engraving. The fumes of the aeid must be anxiously avoided, and the hands guarded with very thick gloves, as the burns produced by the least quantity of the acid, gives the most excruciating pain, or rather tortures.

The nature of fluoric acid is still disputed amongst theoretical chemists; and several different opinions are held by them on the subject.

According to Berzelius, the acidum fluoricum is a compound of a hypothetical principle, fluoricum, with two charges of oxygen, or F:, and its number 275,030.

According to Sir H. Davy, and M. Ampére, fluoric acid is a hydro acid, composed of one atom of a hypothetical principle, called fluorine, equal to 2,250, and one of hydrogen, or 125, so that the charge of the acid is 2,375.

According to Dr. Ure, fluoric acid is a hitherto undecomposed body, and consequently may be esteemed as a principle. He agrees with Sir H. Davy in making its equivalent number 2,375.

The fluoric acid is such a disagreeable subject to meddle with, that chemists are not fond of making experiments upon it.

## CITRIC ACID.

The eitric acid is that whieh gives their aeid taste to lemons, citrons, limes, and many similar fruits. The aeid has several uses in the arts, which renders its proper preparation an objeet of great importance in manufaeturing ehemistry. Like the oxalic aeid, it possesses the property of speedily dissolving the oxides of iron, whieh eauses linen to be, as it is ealled, iron moulded; and henee is used by housewives for the purpose of getting rid of these spots. The dyers make still more use of

it, for no other acid can be employed with such success in enlivening the colours given by safflower: it appears also that it will form with grain tin a liquor which with cochineal, produces scarlet colour superior to the usual dye, especially with silk, and morocco leather. Citric acid whitens and hardens tallow, but as tartaric acid acts nearly as well in this respect, and is considerably cheaper, it is seldom employed for this purpose.

The fruits from which it is procurable, not growing in the countries where the citric acid is most in use; there is a necessity for finding some method of transporting the juice, or some preliminary preparation of it, previous to the manufacture of citric acid.

Citron juice is still exported in large casks from Italy to Germany, and the north of Europe, and was formerly to England, when it was an article of the materia medica, used in the Pharmacopœia under the name of acetositas citri: the juice thus kept deposites much foot, from which foot, when the acid liquor has been drawn off, a species of essence of lemons is distilled; the clear liquor racked off may be kept for a long time, especially if covered with a little sweet oil, and stored in a cool cellar.

Georgius, of St. Petersburgh, attempted to render the juices of these fruits fit for keeping, by exposure of them to cold, but this process is evidently impracticable in those warm climates, where the fruits grow in the open air.

The West Indians are in the habit of adding rum to the juice of limes, a small species of lemon, with a view of allowing it to be transported to Europe: but this addition prevents the juice from being used for the manufacture of citric acid, and it can only be employed for making shrub or other liqueurs.

Scheele having shown the method of making this acid in a pure state, by adding chalk to the juice, and then decomposing the citrate of lime thus formed, by abstracting the lime by means of a sulphuric acid; the addition of chalk to the juice has been used as a means of transporting the material for citric acid rather than the juice itself.

If the juice is freshly expressed, it should stand for some little time to allow the mucilage to settle, which would otherwise mix with the citrate of lime, and, becoming black on the addition of the sulphuric acid, would render the purification of the citric acid difficult.

When the acid is bought, as is usual in Italy, of the farmers in the neighbourhood, it is necessary to examine its strength and purity. The specific gravity of good citron juice is from 1·0312 to 1·0625; the degree of sourness may next be determined by adding to a certain quantity of it the necessary quantity of crystallized, but not powdery, carbonate of soda, to saturate it. The larger quantity of salt of soda it requires, the

stronger is the acidity of the juice. Lest, however, other cheaper acids may be added to increase its apparent strength, some test liquors may be added to separate portions of the juice after it has been filtered through paper. The addition of nitrate of barytes will show if any oil of vitriol has been added, by producing a sediment; a solution of silver in a nitric acid will, by the same means, show if spirit of salt has been added. To detect the addition of aqua fortis, or any other nitric acid, or of vinegar, requires farther research: some of the suspected juice, and also some of known purity, must be saturated, adding chalk until no farther frothing takes place, and when the sediment is fallen down, the specific gravity of the supernatant liquor must be examined; for if any nitrate of lime, or acetate of lime be now present, it will render the mother water of the adulterated juice heavier than the pure.

The purity of bought juice being thus ascertained, it may be converted into citrate of lime for exportation, by stirring it continually while a sufficient quantity of powdered chalk or whiting is added to saturate it, of which it generally takes about one-sixth of its own weight; and then letting it settle until it is clear, the liquid is poured off, and boiling water poured on the sediment, and the whole being well stirred up, it is left to settle, and then poured off; this washing is repeated until the water comes off clear; when this purified sediment, or citrate of lime, is to be dried by exposure to the air and sun.

From this citrate of lime, either fresh, or dry as imported, the citric acid is easily obtained by the addition of oil of vitriol, weakened with four times its weight of water, for fresh moist citrate, or with at least six times for dry citrate. If fresh citrate is used, it will take about nine pounds of oil of vitriol for every ten pounds of chalk or whiting that was used in preparing it: the dry citrate will require about 45 pounds of oil of vitriol to each 100 pounds.

The acid and water being mixed together, are to be poured gradually upon the citrate of lime, and the whole kept constantly stirred; towards the end the mixture becomes more liquid than before, and the sulphate of lime appears to separate from the liquor in crystalline grains. When the whole of the acid is added, the mixture is left for some hours, but is stirred occasionally, and is afterwards assayed, whether too much or too little sulphuric acid has been added. For this purpose, some of the liquor is filtered, and either a solution of nitrate of barytes, or of sugar of lead, in water, is to be dropped into it as long as any sediment falls down, which being separated, is to be itself tried with a nitric acid, diluted with two or three times as much water: if the sediment dissolves entirely

in the nitric acid, the operation has succeeded; but if not, there is an excess of oil of vitriol; if this is but little, the mixture may be heated, which may perhaps, occasion it to unite with some particles of the citrate of lime which has escaped decomposition, and the mixture again assayed; but if the excess of the sulphuric acid is considerable, more citrate of lime must be added, until, on trial, it appears that the whole of the sediment produced is re-dissolved in the nitric acid.

This point being arrived at, there only remains to strain the mixture, to wash out the remains with cold water, to mix these liquors, and to evaporate them for the purpose of crystallizing. The evaporation is first performed in a leaden boiler, until about four parts in five of the liquor have exhaled: it should then be removed to a stone-ware or pewter vessel, set in a copper of water, that the heat may be better regulated than by an open fire. The steaming away of the superfluous water should be stopped occasionally, and a little weak sulphuric acid added to decompose any citrate of lime which may have been dissolved in the acid itself, and the liquor filtered from the sulphate of lime thus separated: for a very small quantity of citrate of lime will impede the formation of crystals, but a slight excess of sulphuric acid is not injurious. The evaporation is to be carried on carefully until the liquor is nearly covered with a skin of fine crystals, when the liquor is to be left to cool. The first crop of crystals is usually dark brown; but if the citrate of lime has been well washed, of a pale brown: by dissolving them two or three times in as little water as possible, straining the solution through a skin of wash-leather, and re-crystallizing, they become white.

The black mother liquor, left after the crystallization, is often flung away, but considering the high price of citric acid, it is best to mix it with ten or twelve times as much water, and then treat it in all respects as though the mixture was fresh citron juice.

Citric acid is sold both in the brown and white state, but at different prices.

Citric acid is considered, by Berzelius, as a combination of four volumes each of hydrogen, carbone, and oxygen, or $H^4\ C^4\ O^4$; and its weight 727,850: Dr. Thomson deducts two atoms of hydrogen, and makes it $H^2\ C^4\ O^4$, and its weight 7,250.

The crystallized acid is made by Berzelius, $H^3\ C^3\ O^3 + HH\cdot$ equal to 659,160; and, when, dried, $H^6\ C^6\ O^6 + HH\cdot$ equal to 1,205,050: Dr. Thomson considers the dry state as merely a bi-hydrate, and equal to 9,500.

### *Lime Juice.*

This is an impure citric acid, prepared for medical use, as a preventive of the scurvy in sea voyages.

The following method of preserving lime juice in the East Indies, is given in the Calcutta Gazettes of September, 1805:—The limes come in between the latter end of October and the middle of November; and, as they arrive successively in the market, the juice is to be squeezed into earthen vessels holding

about fifteen gallons, and in the evening poured into large casks or pipes, from which rum, brandy, or Madeira, has been lately taken out. But, before the juice be poured out of the earthen pans into these casks into which it is to be collected for purification, a red-hot iron bar, about eight inches long, four inches broad, and two inches thick, having an iron chain fixed to it by a hook, is twice quenched in it, turning it equally round on all sides. When the cask, in which the juice is collected in this manner, is nearly full, there is put into every maund, or ten gallons of juice, half a gallon of Bengal rum, full-proof, and it will then settle and clarify itself by the beginning of December, when it may be drawn off for use, either into small casks or bottles.

## TARTARIC ACID.

The process employed at present for obtaining tartaric acid, is that proposed by Scheele in 1770: argol, or crude tartar is to be dissolved in boiling water, and powdered chalk is added to the solution until the effervescence ceases, and the liquid does not redden syrup of violets, or paper stained with litmus or scrapings of radishes. The liquid is cooled and passed through a filter. A quantity of insoluble white powder remains upon the filter, which is the tartarate of lime.

This tartarate must be first well washed, and then mixed with a quantity of oil of vitriol, equal to the weight of the chalk employed (which must have been diluted the day before with water, in the proportion of a gallon of water to each pound of acid,) and the whole well stirred together.

The sulphuric acid uniting with the lime displaces the tartaric acid, and the latter dissolves in the liquid part, which is to be decanted off, and tryed whether it contains any sulphuric acid. This is done by dropping into a small portion of it a little sugar of lead water, as the sediment that will fall down is not dissolvable in acetic acid, if it contains sulphuric acid; but is dissolved if it consists only of tartarate of lead. In the case of the liquid containing sulphuric acid, it must be digested on some more tartarate of lime; if not, it is to be slowly evaporated with a gentle heat, and crystals of tartaric acid, to the amount of about one-third part of the weight of the tartar employed, will be obtained.

Lime has been substituted by Vauquelin for chalk in this process. About 40 parts of slaked lime decompose 100 of argol, or crude tartar, completely; whereas, by Scheele's method, it is only the excess of acid that combines with the chalk.

But when lime is used, the whole tartarate of lime does not separate at once, as a considerable portion is retained in solution by the potasse of the argol or crude tartar. The liquid is, therefore, to be evaporated to dryness and gently heated; and then, by lixiviating the mass, and evaporating the water used to wash it, potasse will be obtained in a state of considerable purity; and the washed tartarate may be added to the

main quantity, or acted upon separately by weak sulphuric acid, as the other portion.

With the same view of separating all the tartaric acid from the argol, Thenard, after saturating the solution of argol with chalk, in Scheele's method, adds solution of chalk in muriatic acid, until it no longer causes a sediment to separate; and thus operates the entire decomposition of the argol, or bi-tartarate of potasse.

Tartaric acid is also preparable by dissolving four pounds of argol in three gallons of water, and adding, gradually, one pound of oil of vitriol. The liquor must be evaporated to one half, and then filtered to separate the sulphate of potasse. The evaporation is then continued, and the liquor filtered from time to time to separate the sulphate: the evaporation is continued to a syrup, and thus about two pounds of crystallized tartaric acid may be obtained.

Tartaric acid is used by the calico-printers to discharge false prints, by candle melters to whiten tallow; it is also used to make lemonade, as being cheaper than the citric acid.

According to Berzelius, dry tartaric acid is composed of $H^5$ $C^4$ $O^5$ and its atomic weight is 834,490; that of the tartras hydricus, or crystals of tartaric acid, 947,760: Dr. Thomson states the dry acid as $H^2$ $C^4$ $O^5$ or 8,250, and the crystals, holding a single atom of water, 9,375.

## OXALIC ACID.

Oxalic acid is seldom prepared expressly, because it is procured in the manufacture of several other substances, so that it is not economical to prepare it expressly. The following, however, are two modes of preparing it.

To twenty-four pounds of starch, divided among several tubulated retorts, and all placed in one common sand-bath, is added seventy-two pounds of common nitric acid. After a short time the starch begins to dissolve, decomposition takes place, and nitrous gas is evolved. When this action has ceased, twenty-four pounds more of nitrous acid is added, and a slight degree of heat applied until all action has ceased. The liquid is then poured off into earthen pans to crystallize. About five pounds of oxalic acid is obtained. To the mother waters twenty-four pounds of nitric acid is afterwards added, at different times, which gives about two pounds and a half more crystals. This is repeated a third and a fourth time, and their whole produce of oxalic acid is nearly equal to half the starch employed. Oxalic acid is purified by dissolving and re-crystallizing it to separate the nitric acid.

The other mode is this:—To any quantity of nitric acid add molasses, gradually, in the proportion of one pound of molasses to six of the acid employed. A gentle heat is to be applied to the mixture, and nitrous oxide escapes in abundance.

When the molasses is entirely dissolved, distil off part of the acid till the whole has a thick syrupy consistence, and on cooling this will be found to crystallize; the crystals being oxalic acid, nearly equal in weight to half the quantity of molasses employed. The crystals must be dissolved and re-crystallized.

Oxalic acid has also been obtained by distilling nitric acid upon wool.

Oxalic acid, dissolved in water, is employed by calico-printers to destroy or lighten colours which are produced by iron. It is also used in domestic economy, to remove iron moulds, and to take out spots of ink from furniture, or instruments, which it does with the greatest facility. The analytical chemists use it as a test liquor to discover the presence of lime in mineral waters, as it separates that earth from all other acids, and forms with it a solid body little soluble in water, and hence falling down in the form of a white powder. It is also popularly employed to cleanse boot tops, and as its crystals have a considerable resemblance to those of Epsom salt, which is also in popular use as a purgative, several unfortunate accidents have happened through its being taken by mistake, as the corrosive power of this acid is very great, when taken in the same dose as Epsom salt.

Oxalic acid was thought by Berzelius to contain hydrogen even in its dry state, but he has since ascertained that this is not the case: its composition on the Lavoisierian hypothesis is $C^2\ O^3$; and its atomic weight, by Thomson, is, of course, 4,500.

## BENZOIC ACID.

Benzoic acid was described as long ago as 1608, by Blaise de Vigenere, in his treatise on fire and salt, under the name of *Flowers of Benzoin*, because it was obtained by sublimation; but is now denominated benzoic acid.

The usual method of obtaining this acid is to put a quantity of benzoin, coarsely powdered, into an earthen pot, to cover the mouth of the pot with a cornet of brown paper, and then to apply a very moderate heat. The benzoic acid is sublimed, and attaches itself to the paper. Some use a large house, as it is called, made of pasteboard and laths, and lined with blotting paper, in loose sheets, every time it is used. Some empyreumatic oil is generally carried up, which soils and injures the acid sublimed.

Newman proposed moistening the benzoin with alcohol, and distilling it in a retort with a low heat. The acid comes over immediately after the alcohol, partly in crystals, and partly of the consistence of butter.

Scheele, in 1775, published a different method, which is often used at present. A gallon of water is poured upon four pounds of unslaked lime: and after the ebullition is over, nine more gallons of water are added. Then twelve pounds of finely pounded benzoin are put into a tinned copper boiler, and six pounds of the above milk of lime are first put upon it. They are mixed well together, and thus successively the rest of the mixture of lime and water is added. If it were poured in

all at once, the benzoin, instead of mixing with it, would grow lumpy. This mixture ought to be boiled over a gentle fire for half an hour, and constantly stirred, then suffered to stand quiet for an hour, in order that it may settle. The supernatant limpid liquor is poured off into a stone-ware vessel. Upon the remainder in the pan ten more gallons of water are poured; they are boiled together for half an hour, then taken from the fire, and left to settle. The supernatant liquor is added to the former; and upon the residuum some more water is poured: it is boiled as aforesaid, and the same process is repeated once more. All the residuums are at last put upon a filter, and hot water several times poured upon them. All these clear yellow liquors and decoctions are mixed together, and boiled down to two gallons and a half, which are then to be strained into another glass vessel.

After they are grown cold, muriatic acid is to be added, and constantly stirred, till there be no farther precipitation, or till the liquid tastes a little sourish. The benzoic acid, which was before held in solution by the lime, falls down in the form of a fine powder.

Mr. Hatchett has observed, that on digesting benzoin in sulphuric acid, a great quantity of beautifully crystallized benzoic acid is sublimed. This process is the simplest of all, and yields the acid in a state of purity; it claims, therefore, the attention of manufacturers.

Benzoic acid is also obtainable in large quantities from the urine of grass-eating animals, as horses, or cows; by merely boiling it down to a small quantity, and then adding muriatic acid; the benzoic acid separates and falls to the bottom of the liquid. It may also be obtained by adding muriatic acid to the water that drains from dunghills. The acid thus prepared has not the fine scent of that procured from benzoin; but this scent may be given it by subliming it with three quarters of an ounce of benzoin to the pound.

Benzoic acid is not used, except in making the popular medicine, paregoric elixir; and in a few articles of perfumery.

The crystals of benzoic acid contain no water, and are estimated by Berzelius to be composed of $H^{12}$ $C^{15}$ $O^3$ equal to 1,509,550. Dr. Thomson considers them as $H^6$ $C^{15}$ $O^3$ equal to 1,500, which is in effect the same, $H^2$ of Berzelius, being, as has been shown in p. 352, H of Dr. Thomson.

### GALLIC ACID.

This acid may be obtained by nut-galls; by merely infusing them in water, and straining the infusion, and setting it by till it has dried up: the sides of the vessel, and the under surface of the dry mass, will be found covered with small yellowish crystals of gallic acid, which may be purified by solution in

spirit of wine, and distilling to dryness. This, the process of Scheele, is simple but tedious.

Friedler orders an ounce of galls to be boiled in a wine pint of water, to a half: add to this the sediment (previously well washed) produced by adding carbonate of potasse water to a solution of two ounces of alum in water. The next day filter off the liquid, and run warm water through the sediment till the liquid no longer renders copperas water black: on evaporating the liquid, fine needle-like crystals of gallic acid will be obtained.

Barruel advised Thenard to mix a solution of white of egg with the infusion of nut-galls, until the infusion ceases to become clouded, to filter the liquid, evaporate to dryness, dissolve the dry mass in spirit of wine, again filter, and distil off the spirit to the proper degree for the formation of gallic acid.

Gallic acid is used as a test liquor for iron, in analytical chemistry; for washing over decayed writings to restore their legibility; and scarcely for any other purpose.

Gallic acid, according to Berzelius, is $H^6 C^6 O^3$ equal to 791,780. Dr. Thomson has not thought it worth his attention in his late work.

## SUCCINIC ACID.

When amber is distilled a volatile salt is obtained, which is mentioned by Agricola under the name of *salt of amber;* but its nature was long unknown. Boyle was the first who discovered that it was an acid. From succinum, the Latin name of amber, this acid has received the apellation of succinic acid.

It is obtained by the following process:—A retort is filled half full with powdered amber, and the powder covered with a quantity of dry sand; the retort is placed in a furnace, a receiver luted on, and fire applied. There passes over first an insipid phlegm, then a weak acid, which, according to Scheele, is the acetic. The succinic acid then attaches itself to the neck of the retort in the form of crystals; and if the distillation be continued, there comes over at last a thick brown oil, which has an acid taste.

The succinic acid is at first mixed with a quantity of oil. It may be made tolerably pure by dissolving it in hot water, and putting upon the filter a little cotton, previously moistened with oil of amber. The acid is then to be crystallized by a gentle evaporation; and this process is to be repeated till the acid be sufficiently pure. Guyton de Morveau has shown that it may be made quite pure by distilling from it a sufficient quantity of nitric acid, taking care not to employ a heat strong enough to sublime the succinic acid.

As succinic acid is scarcely used for any other purpose than in preparing the succinate of ammonia to be used as a chemical agent in separating iron from

acid solutions, a far greater quantity than is required might be collected by saving the vapours that arise in melting amber for making amber varnish.

Succinic acid crystals do not contain any water of crystallization. According to Berzelius, their composition is $H^4\ C^4\ O^3$ equal to 627,850; and Dr. Thomson makes it $H^2\ C^4\ O^3$ or 6,250, which is the same thing in other words. Hence, according to the Glasgow professor, its composition is, so far as remote principles are concerned, the same as that of dry acetic acid, although so different in respect to their union with water, as it requires 100 grains of this liquid to dissolve a single grain of crystallized succinic acid.

### PRUSSIC ACID.

This acid was originally called the *acid of Prussian blue*, then, by contraction, the *Prussian acid*, and, for uniformity of name, the *prussic acid:* the theoretical chemists call it now *cyanic acid*, or *hydro-cyanic acid.*

The original process for obtaining it, as given by Scheele, who first separated it, was as follows:—Mix together ten parts of Prussian blue, in powder, five parts of red oxide of quicksilver, and thirty parts of water, and boil the mixture for some minutes in a glass vessel. The blue colour disappears, and the mixture becomes yellowish green. Pour it upon a filter, and after all the liquid part has passed, pour ten parts of hot water through the filter to wash the residuum completely.

Pour the liquid that passes upon one part and a half of clean iron-filings, quite free from rust. Add, at the same time, one part of concentrated sulphuric acid, and shake the mixture. The iron-filings are dissolved, and the quicksilver, formerly held in solution, is precipitated in the metallic state. The mixture is distilled in a gentle heat, the colouring matter came over by the time that one-fourth of the liquor had passed into the receiver. It is mixed, however, with a small quantity of sulphuric acid; from which it is separated by distilling a second time over a quantity of carbonate of lime.

The sulphuric acid may be also separated by means of barytic water. La Planche recommends one-sixth only to be distilled over, and this to be rectified by means of a gentle fire, over one-two hundredth of carbonate of lime, distilling off afterwards, by means of a gentle fire, three-fourths only of the whole. The acid is obtained of a uniform strength by this process.

Gay Lussac obtained his hydro-cyanic acid by distilling crystallized deuto-cyanuret (cyanide, or prussiate, as it is also called) of quicksilver along with two-thirds its weight of slightly-fuming hydro-chloric acid, or muriatic acid, in a stoppered retort. The neck of the retort must be prolonged for about two feet, by a glass pipe of at least half an inch bore, placed horizontally, and containing, in the end next the retort, small pieces of white marble, the remaining two-thirds being filled with chloride of calcium, or muriate of lime. To the

end of this pipe a small receiver must be luted, and be kept cool by a freezing mixture. Hydro-cyanic acid, along with muriatic acid and watery vapour, will be disengaged on gently heating the retort, the last two of which will be condensed by the materials in the pipe, while the acid, by successively heating the different parts of the pipe, may be driven onwards to the receiver.

On repeating this process, Vauquelin found the product of hydro-cyanic acid extremely small. He succeeded better by passing a current of sulphuretted hydrogen gas, produced by acting on sulphuret of iron with sulphuric acid, very slowly through a glass pipe slightly heated, and filled with prussiate of quicksilver, its extremity ending in a receiver, which was kept cool by a mixture of snow and salt. The process was carried on till the extremely fœtid smell of sulphuretted hydrogen was discovered in the receiver. The hydro-cyanic acid he obtained amounted, in weight, to one-fifth that of the prussiate of quicksilver. To avoid any inconvenience from the process being carried too far, some white-lead was placed at the end of the tube next the receiver, in order to absorb the sulphuretted hydrogen that might pass undecomposed.

The action of this acid upon the nervous system of animals is so strong, that a single drop applied to the tongue or eye of a large dog, instantly deprives it of life; but, as modern physicians, on the present fashion of employing the most powerful drugs, have dared to use it in consumptive complaints, great caution is necessary to be taken in its preparation, to secure uniformity of strength.

Some obtain their prussic acid, for medical purposes, by dissolving prussiate of quicksilver in eight times its weight of water, and pass a current of sulphuretted hydrogen gas through the solution, till the liquid contains a slight excess of it, which may be separated by a little white lead, after which the fluid may be filtered for use.

The process adopted at Apothecaries' Hall, London, is the following:—One pound of prussiate of quicksilver is put into a stoppered retort with six pints of water and a pound of muriatic acid, specific gravity 1·16; a capacious receiver is luted to the retort, and six pints are distilled over. The specific gravity of the product is 0·995: it must be preserved in bottles excluded from the light, and being subject to decomposition, should not be prepared in large quantities at a time.

M. Majendie says, that the medical properties of prussic acid, prepared according to Scheele's method, are not sufficiently determinate, on account of the arbitrary nature of the process. It is better to use M. Gay Lussac's acid, taking care that it be properly diluted, by adding six times its measure, or eight times and a half its weight, of distilled water.

Prussic acid, free from water, according to Berzelius, is composed of $C^2 H^2$

NO equal to 339,560; which the chemists of South Europe express by $C^2$ Az H; and Dr. Thomson makes its atomic weight 3,375.

### LIQUID HYDRO-SULPHURIC ACID.

This was at first called *water impregnated with hepatic air; or gas;* then *water impregnated with sulphuretted hydrogen gas:* the German chemists call it *hydro-thionic acid.*

As it is only used by analytical chemists, to discover the presence of certain metals in a compound mass, it is only prepared in small quantities, and with great care to avoid impurities. Common antimony ground, is put into a retort, and four times its weight of strong muriatic acid is poured upon it; a file of four or five bottles are connected with the retort by pipes, that next the retort has a small quantity of water put into it to absorb the muriatic acid that may come over; the two or three next are half filled with water to absorb the sulphuretted hydrogen gas that is disengaged, and the last with potasse water to absorb any portion of sulphuretted hydrogen gas that may escape the action of the water, and prevent its disagreeable smell of rotten eggs from filling the laboratory.

The sulphuretted hydrogen gas which forms liquid hydro-sulphuric acid, is esteemed, by Berzelius, as S $H_2$, equal to 213,600; and, by Dr. Thomson, as S H, equal to 2,125, which is the same in effect.

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Besides these simple acids, there are other acid compounds, that act in many cases as simple acids, although they contain small portions of alkaline matters.

### *Aqua Regis.*

This having been the first solvent that was discovered for gold, the king of metals, was called by this name, signifying the king's water.

The original and proper aqua regis is made by adding four ounces of common salt to an avoirdupois pound of aqua fortis. Homberg says, aqua regis is of proper strength to dissolve gold, when a bottle, holding sixteen ounces of water, holds seventeen ounces of the acid; that is to say, when it is of the specific gravity 1·062.

The theoretical chemists are not agreed respecting the changes that take place in making this preparation.

### *Aqua Regis made with Sal Ammoniac.*

This is made with sal ammoniac instead of common salt, and, like the common aqua regis, dissolves gold; but is more expensive.

In consequence of the presence of ammonia, it forms fulminating gold by adding carbonate of potasse.

### *Keir's Aqua Regis.*

When to a mixture of oil of vitriol with saltpetre a saturated solution of common salt in water is added, a powerful aqua regis is produced, capable of dissolving gold and platinum; and this aqua regis, though composed of liquors perfectly colourless, and free from all metallic matter, acquires at once a bright and deep yellow colour.

The addition of dry common salt to a concentrated mixture of sulphuric and nitric acids, produces an effervescence, but not the yellow colour; for the production of which, a certain proportion of water is thought by Keir to be necessary.

### *Keir's Aqua Reginæ.*

This name is given to this acid liquor on account of its dissolving silver, and having little or no action on other metals, unless water is added; hence it may be metaphorically said that it is the only bath in which the queen of metals can wash herself without intrusion.

It is made by pouring eight or ten pounds of oil of vitriol upon a pound of refined saltpetre.

It is used at Birmingham to recover the silver from the waste scrap of the platers.

### *Essential Salt of Wood-Sorrel.*

Wood-sorrel grows abundantly in Switzerland, and is collected and crushed in wooden mortars, with a hole in the side, by means of large wooden hammers, which are lifted up by the sweepers of the arm of water-mills. The juice thus obtained is cleared by settling for a few days, then strained, evaporated to a pellicle, and set by to crystallize.

The plant yields about half its weight of juice, and from 140 to 200 pounds of the plant are required to furnish a pound of the salt; which is carried from its native mountains to all parts of Europe.

A similar essential salt has also been procured from the common sorrel, but not so easily: both constitute the basis of what is sold by the name of essential salt of lemons; being, for this purpose, mixed with an equal weight, or even more, of cream of tartar.

The genuine salt forms, with sugar and water, an agreeable cooling beverage, much used on the continent, not being so griping as cream of tartar: it is also used, like pure oxalic acid, to take out iron-moulds or ink-spots, and as a test for lime.

This salt is the bi-oxalate of potasse of the theoretical chemists, and may also be formed by dropping carbonate of potasse water into liquid oxalic acid, when it falls in the form of small crystals, but if too much carbonate of potasse is added, the crystals do not separate. Berzelius says, the bi-oxalas kalicus $K \cdot O^{-4}$ is combined with two atoms of water, and its atomic weight 3,211,740. Dr. Thomson says it is composed of $K \cdot O^{-2} + 2\,H$, and makes its weight only 17,250; which is widely different.

### *White Argol.*

This is also called white crude tartar; it is obtained from white wines by keeping, as it settles and forms a crust on the sides of the cask. The wines of the countries in which the grape does not thoroughly ripen, are those which furnish the greatest quantity.

It is used for the manufacturing of cream of tartar; for determining and promoting the fermentation of saccharine liquids, being a neater article than yeast for that purpose; for making a carbonate of potasse; for dyeing; and in medicine; being less apt to gripe than cream of tartar, which is prepared in copper vessels.

White argol is a bi-tartarate of potasse mixed with some tartarate of lime, and a little of the extractive and other carbonaceous matters of the wine.

### *Red Argol.*

This is deposited from the red wines, and contains more of the extractive and other carbonaceous matters of the wine than white argol.

It is used for making a carbonate of potasse for the dyers; for making a fine black for copper-plate printing; for dyeing; and by metallurgic chemists for making their black flux.

### *Cream of Tartar.*

This is also called *crystals of tartar;* and by theoretical chemists, *acid tartarate, acidulous tartarate, bi-tartarate,* or *super-tartarate of potasse;* and in the north of Europe, *bi-tartras kalicus.*

It is manufactured by dissolving white argol in water, adding about one-twentieth of its weight of white clay to absorb the oily and other particles in the argol which colour it, then filtering the liquid, evaporating to a skin, and setting it by to crystallize: if the crystals are not sufficiently white, the process must be repeated.

Cream of tartar has been much used to form an acidulous drink for summer use; but as the cream is prepared in copper vessels, and contains a minute portion of copper, it is apt to gripe. In chemistry it is used as an acid to form emetic tartar, and some other potasse-tartarates.

The composition of cream of tartar, according to Berzelius, is $K \cdot\cdot T^{-4}+2 (H^2 O,)$ and its atomic weight 4,742,660; but according to Dr. Thomson, $K. T^{-2} + 2 H^{\cdot}$, or 24,750.

Besides these acids which are in use, the analytical and theoretical chemists mention several others; but as they have not yet been discovered to possess any useful properties, a bare enumeration of their names would be misplaced in a treatise on Operative Chemistry.

## ALKALIES.

Alkalies in their original signification meant only the caustic salts extracted from the ashes of plants by washing the ashes with water, and boiling down the liquor to dryness; but at present the chemists denote, by this term, whatever forms a crystallizable compound with the four most usual acids, namely, the sulphuric, nitric, muriatic, or acetic: so that the term, alkaline, has become a mere correlative to acid.

The usual alkalies namely, potasse, soda, ammonia, and lime, have a very caustic taste; are soluble in water, and the solution changes the blue colour of syrup or violets to green; they corrode and dissolve animal flesh, and unite with olive oil; the three first forming with it a compound dissolvable in water.

As the strength of acids is compared by ascertaining the quantity of carbonate of soda which they saturate; so that of alkalies may be compared by ascertaining the relative quantity of concentrated sulphuric acid, or oil of vitriol, that they are able to saturate.

Dr. Ure, who is fond of instrumental chemistry, improved an alkalimeter of M. Descroizilles, for the purpose of ascertaining the strength of alkalies, not in general, but of each kind in particular: but the general use of this instrumental chemistry is to be discouraged, although particular individuals may occasionally apply it to their peculiar uses.

### POTASSE, OR KALI.

The original name of this family of alkaline salts was *vegetable alkali*, contracted by Dr. G. Pearson into *veg-alkali*. When about forty years ago a rage for new naming every article used in chemistry was begun, the French nomenclators named it *potasse*, which some have anglicised into *potass*, others into *potassa*, or even *potash*, disregarding the equivocations thus produced. Dr. Black called it *lixiva;* Kirwan, *tartarine;* Bergmann, *potassinum;* Hopson, *spodium;* others have revived the ancient term, *kali*, which is retained by Berzelius, and of course used by the Swedish, Danish, Saxon, and Prussian medical faculty, who have adopted his nomenclature, with occasional slight alterations amongst this variety, potash, potass, potassa, or potasse, and kali, still keep their ground.

Pure potasse or kali is obtainable by burning potassium in oxygen gas, but is not used.

Sir H. Davy found that potassium, heated in a small quantity of atmospheric air, formed a grayish mass. This Berzelius considers as the protoxide of potassium, and calls it *sub-oxidum kalicum*, K· equal to 1,079,830: dry potasse, called by him *oxidum kalicum*, or simply *kali*, is K·· equal to 1,179,830; but Dr. Thomson considers potasse as the protoxide, and of course the atomic weight of potassium to be only half that assigned by Berzelius, so that potasse is K·, equal to 6,000.

#### *Pearl-Ash.*

This is obtained from the ashes of wood by washing out the salt with water, and evaporating the ley to dryness.

Most trees are known to be fit for this purpose, as the ashes of them all, burnt promiscuously in house fires, make a very

strong ley fit for soap. The hickory, a most common tree in American woods, produces the purest and whitest ashes, of the sharpest taste, and strongest ley, of any wood. Stick-weed is said to do the same, which is a common American weed. For this reason the ashes of both these plants were used by the Indians there instead of salt, before they learnt the use of common salt from the Europeans. The ashes of damaged tobacco, or its stalks, stems, and suckers, of which great quantities are thrown away, and rot and perish, are very fit for pearl-ash, as they contain a great deal of salt, and are well known to make a strong ley. In England wormwood was frequently used for this purpose.

On the other hand, pines, firs, sassafras, liquid amber, or sweet gum, and all odoriferous woods, and those that abound with a resin or gum, are unfit for making pearl-ash, as their ashes are well known to make a very weak ley.

Besides these, that contain little or no salt, there are some other vegetables that afford a large quantity of it, but make a bad kind of pearl-ash, at least for many purposes, on account of a neutral salt with which they abound. This seems to have been the case of the potash made in Africa; in a manufacture of that commodity set up there by the African company, which Mr. Houston, who was chiefly concerned about it, tells us, in his Travels, proved so bad, on account of a neutral salt it contained, that the manufacture was left off on that account.

The plants used for making pearl-ash should likewise be burnt to ashes by a slow fire, or in a close place; if the plants are burned solely for this purpose. For the difference between burning wood in a close place and the open air is so great, that the quantity of ashes obtained from one is more than double the other.

Lundmark burnt a quantity of birch in a close stove, from which he obtained five pounds of ashes; whereas, the same quantity of the same wood burnt in the open air, yielded only two pounds.

It is for this reason that most people who make potash or pearl-ash, burn their wood in kilns, or pits dug in the ground, though the Swedes burn it in the open air.

Dr. John, of Berlin, has recently found, by experiment, that rotten and decayed wood yields more alkali than sound wood. So Cleaveland, in his mineralogy, says that two bushels of the ashes made by burning the dry wood in hollow trees, contained as much alkali as eighteen bushels of ashes made from sound oak.

One thousand pounds of the following vegetables yielded the under-stated quantity of ashes, and these, by washing, produced salt, mostly carbonate of potasse, as follows:—

| | Ashes. | Salt. |
|---|---|---|
| Fumitory | 219 pounds. | 79 pounds. |
| Wormwood | 97 | 73 |
| Stinging nettle | 107 | 25 |
| Vetches, or tares | — | 27 |
| Bean stalks | — | 20 |
| Cow thistle | 105 | 20 |
| Stalks of maize | 88 | 18 |
| Great river rush | 39 | 7 |
| Fern | 40 | 6 |
| Vine cuttings | 34 | 5 |
| Common thistle | 40 | 5 |
| Feathered rush | 43 | 5 |
| Elm | 24 | 4 |
| Sallow | 28 | 3 |
| Oak | 13 | 1½ |
| Beech | 6 | 1½ |
| Hornbeam | 11 | 1¼ |
| Poplar | 12 | ¾ |
| Clover | — | ¾ |
| Fir | 3 | — |

It having been stated that potato tops might be used with great advantage for obtaining pearl-ash, M. Mollerat made the following experiments on a hectare, or two acres and nearly two roods of ground, planted with a very productive potato, called in France, the yellow patraque.

| Period of cutting. | Cuttings produced pearl-ash, in pounds. | Crop of potatos in tuns. |
|---|---|---|
| Immediately before flowering | 424 | 2 |
| Immediately after flowering | 380 | 16 |
| A month later | 150 | 30 |
| A month later than the last | 130 | 41 |
| Another month later | the same. | the same. |

According to Vauquelin, two ounces of American potash contained 857 grains of potasse combined with 119 of carbonic acid and water, 154 of sulphate of potasse, 20 of common salt, and 2 of indissoluble matters.

The species sold commonly as pearl-ash, contained 754 grains of potasse combined with 308 of carbonic acid and water, 80 of sulphate of potasse, 4 of common salt, and 6 of indissoluble matters.

## *Potash.*

The art of converting wood ashes into potash is practised in Russia, Sweden, and other northern countries, as it was disclosed by Dr. Lundmark, which has been imitated in other places.

They have many woods of beach in Smoland, and other parts of Sweden, in want of which they take alder; of these they use only the old and decaying trees for this purpose, which they cut to pieces, and pile in a heap, to burn them to ashes, on the ground, by a slow fire. They carefully separate these ashes from dirt or coals in them, which they call raking them, after which they carry them to a hut built in the woods for this purpose, till they have a sufficient quantity of the ashes. They then choose a convenient place, and make a paste of these ashes with water, by a little at a time, in the same manner, and with the same instruments, as mortar is commonly made of clay or lime. When this is done, they lay a row of green pine or fir logs on the

ground, which they plaster over with this paste of ashes: over this they lay another layer of the same straight logs of wood, transversely or across the others, which they plaster over with the ashes in the same manner; thus they continue to erect a pile of these logs of wood, by layer over layer, and plastering each with their paste of ashes, till they are all expended, when their pile is often as high as a house. This pile they set on fire with dry wood, and burn it as vehemently as they can; increasing the fire from time to time, till the ashes begin to be red hot, and run in the fire. Then they quickly overset their pile with poles, and while the ashes are still hot and melting, they beat and clap them with large round flexible sticks, made on purpose, so as to incrust the logs of wood with the ashes: by which the ashes concrete into a solid mass, as hard as stone, when the operation has been rightly performed. This operation they call, walla, or the dressing. Lastly, they scrape off the salt, thus prepared, with iron instruments, and sell it for potash. It is of a bluish dark colour, not unlike the scoriæ of iron, with a pure greenish-white salt appearing here and there in it.

All the potash we have from Russia, Sweden, and Dantzic, is made in this manner. It is, however, generally observed, that the Russian is the best of these, on account of the greater quantity of salt in it. Now if, in the preceding process, we make a paste of the ashes with ley instead of water, it is plain the potash will be impregnated with more salt, and make all the difference found so between these sorts of potash. This, then, is likely to be the practice in Russia, where their wood may also be better for this purpose, and afford more salt. This is well known to be the case of different kinds of wood, thus, Lundmark tells us, he obtained two pounds, 27-64ths, of salt out of eight cubic ells of poplar, which was very sharp and caustic, but the same quantity of birch afforded only one pound of salt, and that not so strong, and fir hardly yielded any at all.

Potash differs considerably from pearl-ash, for the best Russian potash, as it is brought to us, is in large lumps, as hard as a stone, and black as a coal, incrusted over with a white salt, that appears in separate spots here and there in it. 2. It has a strong, fœtid, sulphurous smell and taste, as well as a bitter and lixivial taste, which is rather more pungent than other common lixivial salts. 3. A lixivium of it is of a dark green colour, with a very fœtid sulphurous smell and bitter sulphurous taste, somewhat like gunpowder, as well as sharp and pungent like a simple lixivium. 4. Though it is as hard as a stone, when kept in a close place, or in large quantities together in a hogshead, yet, when laid in the open air, it turns soft, and some pieces of it run into a liquid. 5. It readily dissolves in warm water, but leaves a large sediment, of a blackish gray colour, like ashes, which is in a fine soft powder, without any dirt or coals in it, that

are to be observed in most other kinds of potash, or kelp. 6. As it is dissolving in water, there is scummed off from some lumps of it a dark purple bituminous substance, like petroleum or tar, which readily dissolves in the lixivium. 7. This, or any other true potash, or a lixivium made of them, will presently tinge silver of a dark purple colour, difficult to rub off: while a pure alkaline salt has no such effect. Geoffrey found that most of these properties may be given to pearl-ash by melting it with charcoal.

Pieces of this potash, while being boiled in water, made a constant explosion like gunpowder, which was so strong as not only to throw the water to some height, but lift up and almost overset a stone cup in which it was boiled. These explosions were owing not so much to the included air, which some perhaps may imagine, as to the sulphurous parts of the composition expanding and flying off; for this boiled lixivium had neither the green colour, nor fœtid sulphurous smell and taste, at least in any degree like what it has when made of the same potash by a simple infusion in warm water.

According to M. Vauquelin, two ounces of various kinds of potash contained as follows:

Russian potash contained 772 grains of potasse combined with 254 of carbonic acid and water, 65 of sulphate of potasse, 5 of common salt, and 56 of indissolvable matter.

Dantzic potash contained 603 grains of potasse combined with 304 of carbonic acid and water, 152 of sulphate of potasse, 14 of common salt, and 79 of indissolvable matter.

Treves potash contained 720 grains of potasse combined with 199 of carbonic acid and water, 165 of sulphate of potasse, 44 of common salt, and 24 of indissolvable matter.

Vosges potash contained 444 grains of potasse in combination with only 16 of carbonic acid and water, 148 of sulphate of potasse, 510 of common salt, and 34 of indissolvable matter.

### *English Potash.*

There is another way of making potash, practised chiefly in England, with ashes of fern, or wood of any kind: they make a ley, which they reduce to what they call potash, by burning it with straw. To do this, they place a tub full of this ley near a clean hearth of a chimney, in which they dip a handful of loose straw, so as to take up a quantity of ley with it. The straw thus impregnated with ley they carry as quickly as they can, to hold it over a blazing fire on their hearth, which consumes their straw to ashes, and at the same time evaporates the water from the salts of the ley. Over the blaze of the first parcel of straw they burn another dipped in ley in the same manner. This they continue to do till their ley is all expended. By this means the coals and ashes of the straw, and salts of the ley, are left on the hearth, and concrete together into a hard solid cake of a grayish black colour, which they scrape off and sell for potash.

This potash is unfit for some purposes, and not above half the value of the foreign.

[It is a little remarkable, that no mention is made by the author, of American pot and pearl-ashes; they are well known in the English market, and extensively used in the arts of Great Britain, possessing a decided superiority in point of purity, over those of any other country. The processes of manufacturing the pot and pearl-ashes in the United States and in the Canadas, is very simple, but by no means so economical as they might be. In general, the clearing the land of wood, is the primary, and the manufacture of these articles only a secondary, object. The wood is usually cut into lengths of eight or nine feet and thrown into piles of one, two, or more cords, and, when partly seasoned, set on fire. The woods which are cut in summer are said to be the most productive in alkali. The ashes resulting from the combustion are, when cold, gathered up and put into large tubs, the bottoms of which are covered to the depth of 6 or 8 inches with brush-wood, and over that with a layer of three or four inches of straw. Water is then poured upon the top, and suffered to filter through till all the soluble matter of the ashes is extracted. The ley runs off through an aperture near the bottom of the tub designed for that purpose. It is then boiled in large cast-iron kettles till the water is all evaporated, and the matters, which were held in solution, obtained in a solid form: this product is familiarly known to the workmen by the term of *brown salts*, or *salts*, simply; it is of a very dark,—almost black, colour, and a very strong alkaline and acid taste, and consists of a very large proportion of potash, mixed with more or less carbonaceous matters, vegetable salts of potash, and small portions of silex and other earths. To convert these brown salts into potash they are again thrown into a cast-iron kettle of considerable thickness, fused and subjected for an hour or two to a full red heat after the mass is perfectly liquid. By this means the carbonaceous matters are for the most part decomposed and burned out. The remaining product is, when cold, broken up and packed in tight casks, and constitutes the American potash of commerce. It contains from five to twenty per cent. of pure potash, combined or mixed with variable proportions of carbonic acid, and compound carbonaceous matters, silex and other earths, the proportions and quantities of the latter depending very much upon the care which may have been used in collecting the wood ashes after the combustion. The potash of commerce is usually divided into four sorts according to the degrees of purity of each.

If the salts obtained by the evaporation of the ley in the first instance are redissolved in a small quantity of water, there will be a considerable deposite of less soluble earthy substances, and

the clear liquor when evaporated, will afford a much purer product than that obtained in the common way, and the potash resulting from it will be proportionally purer. This plan is indeed adopted by many potash makers. Unskilful manufacturers of potash are sometimes much troubled with the presence of nitrate of potash in melting down the brown salts; this difficulty is remedied by mixing with the brown salts, previous to melting, a small quantity of powdered charcoal. It is probable that nitric acid, (and, of consequence, nitrate of potash,) is always a product of the combustion of wood in the open air; but the quantity varies with the circumstances of the combustion, and in ordinary cases, the carbonaceous matter in the brown salts are sufficient to decompose it without the addition of charcoal.

In the manufacture of pearl-ash the process is the same up to the production of the brown salts. They are then thrown into a reverberatory, and calcined till the whiteness of the product indicates the entire dissipation of all carbonaceous and volatile matters. The salts are, of course, stirred or raked frequently, during this process, which is called *pearling*. The product is the pearl-ash of commerce, a sub-carbonate of potash, uncontaminated by vegetable matter, but containing more or less of earthy impurities, derived principally from the bed upon which the wood was burned. Particular care is taken that the temperature do not rise so high in the pearling as to cause the salt to melt, as upon this circumstance the superior purity of the pearl-ash in regard to carbonaceous substances, depends.

The immense supplies of pot and pearl-ashes for the arts and for exportation, are, in this country, derived exclusively from the combustion of forest timber. Owing to the great abundance of wood, no attempt has been yet made on an extensive scale to procure them from the smaller tribes of the vegetable kingdom.

The source of potash, as obtained in the combustion of wood, is an unexplained problem in chemistry.]

### *Purified Pearl-Ash.*

This has been ordered under different names, according to the fashion of the times when the College of Physicians published their Pharmacopœias. In the old editions it bore the name of the fixed salt of the plant from which it was extracted, generally *wormwood*. In 1788, it was *prepared kali;* in 1809, *sub-carbonate of potasse*. It is also sold under the name of *salt of tartar*.

It is prepared by pouring half its weight of water upon good pearl-ash, filtering the solution, and evaporating it in copper pans until it becomes perfectly dry, which is particularly requisite, as otherwise it will not acquire the usual granular appearance, by stirring as it cools.

By this operation, the greatest part of the sulphate of potasse and common salt, contained in the pearl-ash, is left upon the filter, but some still remains. It is, however, a carbonate of potasse pure enough for medical and common purposes.

## *Carbonate of Potasse Water.*

This water being used in analytical and docimastic experiments, requires attention as to its purity and strength.

It is usually prepared by throwing a mixture of charcoal powder, with three times its weight of purified saltpetre, by degrees, into a red-hot silver crucible, taking it from the fire as soon as the detonation is complete, washing out the salt with distilled water, and filtering it through well-washed sand or powdered glass. The specific gravity is then to be ascertained, and the solution either reduced by adding distilled water, or, which is more commonly requisite, concentrated by evaporation until the required specific gravity is obtained.

Dr. Henry advises it to be kept of the specific gravity 1·248, as it will then saturate an equal measure of sulphuric acid at 1·135, or of nitric acid at 1·143, or of muriatic acid at 1·074; being thus of equal strength with ammonia water at 0·970, and twice as strong as potasse water at 1·100, pure soda water at 1·070, carbonate of soda water at 1·110, or sesqui-carbonate of ammonia water at 1·046.

The *liquor potassæ sub-carbonatis*, used in medicine, is an impure preparation of this kind, made from purified pearl-ash; it is also called *aqua kali*, and *oil of tartar per deliquium*.

The name of carbonate of potasse has been given by the chemists to the combination of a single charge of potasse with a single charge of carbonic acid; and, by the English medical faculty, to the salt with a double charge of carbonic acid, the bi-carbonate of the chemists: the name carbonate of potasse is thus rendered equivocal, fortunately no sub-carbonate, in the chemical sense of the term, has yet been discovered; so that, by patching together the sub-carbonate of the medical faculty, and the bi-carbonate of the chemical schools, an unequivocal designation of the two articles may be obtained.

## *Aerated Kali.*

The salt sold under the name of aerated kali, is the *carbonate of potasse* of the present medical faculty, and the *bi-carbonate of potasse* of the chemical schools. it is also advertised, by some ignorant uneducated druggists, under the name *ærated kali*, which would, etymologically, signify kali impregnated with æ, brass; whereas the name of the salt is from *a-er*, air, as being surcharged with what was called fixed air.

It may be made by passing carbonic acid gas into purified pearl-ash water; by Glauber's or Woulfe's apparatus; care being taken that the pearl-ash water is not too strong, as in that case the aerated kali crystallizing as it forms, would stop up the pipes. The silica contained in the pearl-ash is separated by not being soluble in water in the saturated salt, and the aerated kali may be crystallized by evaporating the liquor to a pellicle.

M. Curaudou's process of making aerated kali is, to dissolve pearl-ash in water, and incorporate with it dried tan, bran, or

saw-dust, till all the liquid is absorbed. A crucible is filled with this composition, covered with a lid, and the joints luted.

This crucible must be submitted to the heat of a furnace about half an hour, or till it is thoroughly red-hot. When the crucible is cold, put upon a filter all the matter contained in it, and pour on it a sufficient quantity of water to dissolve it quickly. Then evaporate the liquor to a very small quantity; and, after it has been left to cool about twenty-four hours, it will furnish very beautiful crystals of bi-carbonate of potash.

It is more advantageous to perform the operation on a large than on a small scale; as the rapidity with which small quantities cool, frequently prevents the formation of regular crystals.

After all the carbonate, which the ley held in solution, has been obtained, by several evaporations and crystallizations, the mother water may be submitted to calcination with tan, and thus a fresh quantity of crystals of bi-carbonate of potash will be obtained, until the liquor at length becomes more surcharged with other salts than with potash.

Mr. Lowitz has proposed another process.

A quantity of purified pearl-ash is to be dissolved in an equal, or, which will be still better, in double its weight of water; and the solution being filtered, there must be added to it, by small quantities at a time, (the liquor being kept stirred during the whole of the operation,) distilled vinegar, which should be poured down in a thin stream from as great a height as the hand can be held, till neither stirring the liquid with vehemence, nor frequently intermitting the effusion of vinegar, can any longer prevent the effervescence which does at last take place. The fluid must now be filtered, and evaporated over a very slow fire, till a film of salt appears upon it. After it has completely cooled, the impure carbonate of potasse, which has deposited itself in small irregular crystals, is to be separated by filtering the mixture through a linen bag; and the fluid must be evaporated and filtered once or twice more, and the whole of the salt obtained purified by repeated solution and crystallization, till it forms perfectly white and regular crystals.

By this process the carbonate of potasse will not only be freed from the acetate that adhered to it, but likewise from all admixture of carbonate of potasse which will remain behind in the original lixivium.

For the same purpose of obtaining aerated kali, sulphuric acid may be used; but it must previously be diluted with a large proportion of water. In this process, after evaporation, the sulphate of potasse first crystallizes, and then the bi-carbonate. A residuum of carbonate of potasse also remains in the original lixivium.

A bi-carbonate of potasse may be obtained by the means of sulphur, in the following manner:—Any quantity of purified pearl-ash must be dissolved in two or three times its weight of water. The solution must be gently boiled, and flowers of sulphur gradually added, till no more appears to dissolve. The fluid is then to be evaporated very slowly to the point of crystallization, and the crystals obtained purified by repeated solution, filtration, and crystallization from their admixture with sulphuretted potasse and carbonate of potasse.

This method requires far less evaporation of water, and affords crystals of the purest aerated kali. The principle upon which it depends is this: the sulphur only uniting with the potasse of the pearl-ash, causes the carbonic acid to concentrate itself in the remaining potasse; so that if the proper proportion of water has been added in the beginning, the aerated kali frequently deposites itself by crystallization, immediately after the liquor has cooled, without requiring any farther evaporation.

As that part of the carbonic acid, whereby the neutralization of the kali is completed, is so very slightly combined with it, that the slightest increase of temperature causes a part of it to separate in the form of carbonic acid gas, it is therefore very necessary, in purifying this salt, to pay particular attention, in order to prevent the solution from boiling; for the greater heat we employ, the more carbonic acid will be wasted.

In pharmaceutical laboratories, bi-carbonate of potasse may be obtained from the residuum which remains after the distillation of tartar, by lixiviating it without previous calcination, and evaporating the fluid to the point of crystallization, after which, by repeated solution and evaporation, the crystals may be freed from all admixture of common carbonate of potasse.

[The aerated or carbonate of potash, is extensively used in the United States in the domestic manufacture of bread, in medicine and for other purposes. It is very economically prepared by the distillers and brewers from common pearl-ash by suspending it in lumps in a wooden box pierced with holes in the upper part of their fermenting vats, which are always occupied with an atmosphere of carbonic acid. In a few days' time, longer or shorter, according to the quantity operated on, the alkali becomes completely saturated with the acid. The salt prepared in this way, will not have the crystalline form, but is equally useful for all the purposes of the arts. Its purity will of course depend upon the purity of the pearl-ash employed.]

### *Hydrate of Potasse.*

The common hydrate of potasse, sold by the apothecaries as *potassa fusa*, is prepared by merely boiling down their liquor potassæ to dryness, and then pouring it out upon a stone slab,

and cutting it into pieces, from which the air is to be kept carefully excluded.

Berthollet recommends to boil down potasse-water till it acquires a thickish consistence, to add about an equal weight of spirit of wine, and let the mixture stand some time in a close vessel. Some solid matter, partly crystallized, will collect at the bottom; above this will be a small quantity of a dark-coloured liquid; and, on the top, another lighter. The latter liquid, separated by decantation, is to be evaporated quickly in a silver basin in a sand-heat. Glass, or almost any other metal, would be corroded by the potasse. Before the evaporation has been carried far, the solution is to be removed from the fire, and suffered to stand at rest, when it will again separate into two fluids. The lighter being poured off, is again to be evaporated with a quick heat: and, on standing a day or two in a close vessel, it will deposite transparent crystals of pure potasse. If the liquor be evaporated to a pellicle, the potasse will concrete without regular crystallization. In both cases a high-coloured liquor is separated, which is to be poured off, and the potasse must be kept carefully secluded from air.

Hydrate of potasse is composed of a proportion of each, potasse and water, according to Mr. Phillips and others, but Berzelius makes it K: + 2(H H·) equal to 1,404,700; indeed it so strongly retains part of the water, that chemists do not agree how much water 100 parts of it contain. Phillips says 15 parts ·8, Thenard 20, Berzelius 16, Thomson 15·4.

### *Nitre fixed by Antimony.*

For obtaining an impure but very dry and caustic kind of potasse, chemists act upon saltpetre, by means of regulus of antimony.

Four ounces of the regulus is mixed with eight of refined saltpetre, and kept for an hour in a strong fire in a large crucible; four ounces more saltpetre are then added, in another hour four ounces more, and in another hour four ounces more, in all twenty ounces; the heat must, in the end, be so strong, that the mass may swell up and effervesce, and this heat continued until the mass is in quiet fusion, and as fluid as water, when it is to be poured out into a basin, and bruised into pieces.

The extreme causticity of this greenish semi-transparent mass, seems to arise from its not containing water. When spirit of wine is poured upon it, it grows hot, and slakes as violently as quick-lime does with water, the spirit becomes instantly milk white, and, after a short digestion, deep blood red.

### *Potasse Water.*

This water is used in docimastic chemistry, and, must, therefore, be kept as pure as possible. It is usually prepared by mixing refined saltpetre with twice its weight of cream of tartar,

both in fine powder, throwing them into a cast-iron crucible, nearly red-hot, by which a very nearly pure sub-carbonate of potasse will be obtained. This, or any other equally pure sub-carbonate of potasse, is to be mixed with an equal weight of good quick-lime, and five times its weight of distilled water; the whole is boiled together in a basin, until, on filtering a spoonful of the liquid, and pouring lime-water into it, no sediment is formed: the whole is then poured on a strong linen cloth, placed on a colander in the mouth of a funnel: the first liquor that passes is thrown again on the filter. The specific gravity of the filtered liquor being examined, it is boiled down to the required strength. During both the boilings and the filtering, the vessel should be kept covered to prevent the access of the atmosphere, from which the liquid would absorb carbonic acid gas.

Dr. Henry advises it to be kept of the specific gravity of 1·100; so that two measures of it may saturate one measure of sulphuric acid at 1·135, of nitric acid at 1·143, or of muriatic acid at 1·074.

An impure potasse-water, sufficient for medicines, is sold as *liquor potassæ*, and is made from a troy pound of purified pearl-ash, half a pound of quick-lime, and a wine gallon of distilled water, mixed together, and the liquid strained through a cotton bag: the medical faculty order that a wine pint should be of such specific gravity as to weigh sixteen troy ounces. This liquor is also called, in common parlance, *soap-ley*.

Potasse-water should be kept in small bottles, quite full and well stopt; in a large bottle, the atmospheric air gets in every time it is opened, and the water imbibing carbonic acid gas soon gets spoiled, and a sediment is produced on adding lime-water.

### *Sal-enixum.*

This was at one time a favourite nostrum in Germany, and was sold under a variety of names. Its real chemical appellation was *vitriolated tartar*, from its original mode of preparation by Angelus Sala, by adding fixed salt of tartar to very weak copperas-water, filtering the liquid, and crystallizing it by evaporation and rest. It is the *sulphate of potasse* of the new nomenclature.

It is now procured as a secondary product, from the residuum in making nitric acid; adding pearl-ash, wood, or fern-ash, if necessary, to neutralize the sulphuric acid. It contains no water.

This salt is used by workers in metals as a flux, also to impregnate wood to secure it from the dry-rot; and, being very hard, the medical faculty use the crystals to mix with tough gums, that they may be reduced to powder. In France it is used to change the native nitrate of lime into saltpetre, and in the manufacture of potasse alum.

### *Saltpetre.*

The saltpetre used in England is now obtained from the East Indies, where it is produced by nature.

The saltpetre earth, according to Heyne, attracts a little moisture at night, and appears like a black foot dust at the bottom of old walls, or on the streets of populous or old villages. It

does not differ in appearance from that which yields salt or soda; and, indeed, one village or one street frequently contains all the three salts.

The most profitable way of preparing saltpetre is, to evaporate it in shallow basins of mortar.

The earth is swept up every other day, and contains about one-fifth of crude saltpetre. Thunder and lightning are esteemed favourable for its production. After the saltpetre is extracted, the earth is heaped up till the rains are over, and then spread out; in a year or two it yields saltpetre again.

About two gallons of saltpetre earth is collected at the foot of each yard of wall. The saltpetre gained from black cotton ground contains more common salt than that from garden earth.

The pans of mortar are filled about four inches deep, about half is evaporated in four or six days, and the saltpetre begins to crystallize. The first day's product is the purest; the second day's contains about half common salt; the third day's contains scarcely a quarter of saltpetre. The remaining liquid is thrown upon the elixated earth, has a caustic burning taste, and contains scarcely any thing but nitrate and muriate of lime.

Saltpetre is always refined by boiling, adding soap, milk, eggs, twigs of euphorbia tirucalli, and single, refined saltpetre, still contains about a quarter of common salt.

Bengal saltpetre is browner than that of the coast.

If saltpetre is kept or prepared in any apartment, it is difficult (at least in India) to prevent the destruction of the walls by the continual production of the salt.

Saltpetre grounds are not so common as reported, common salt and soda grounds being mistaken for them.

Calcareous earths, impregnated with saltpetre, are found in caverns in limestone, in various places.

The saltpetre earth of Georgia, United States, contains both the nitrate of potash and that of lime; the latter is changed into saltpetre by adding wood ashes; one bushel of earth yields from three to ten pounds of saltpetre, selling there for sixteen cents (eight pence) by the pound.

Kentucky saltpetre earth is similar to this; it is washed, and the ley passed through wood ashes; a bushel yields from one to two pounds of saltpetre.

Similar earths are found at Molfetta, Naples, Hungary, and various other places in Europe.

Kentucky rock ore is a sand-stone which, when broken to fragments, and thrown into boiling water, soon falls into sand; and the liquor strained from it yields, by crystallization, from ten to twenty pounds of nitre from each bushel of stone. This

nitre contains little or no nitrate of lime, and is considered better for gunpowder than that obtained from Kentucky nitre earth.

Masses of saltpetre of several pounds weight, are sometimes found in the fissures of this sand-stone, accompanied with masses of a black bituminous substance of a few ounces in weight.

Similar sand-stones are found in South Africa, according to Barrow.

The saltpetre formerly used in England was extracted from the mortar of old buildings, as it is still in France and Prussia.

The mark the saltpetre workers have to know good mortar for their purpose is, that it tastes acrid and salt when applied to the tongue; but to this it may be also added, that it ought to be of a grayish colour, and such as, when powdered and sprinkled upon burning charcoal, yields some sparks of fire; and the more sparks it gives, the better it is for the purpose. Another character of the goodness is, that these well-impregnated mortars have a certain unctuosity or fattiness to the touch, which other kinds have not.

The finest of all kinds of mortar for saltpetre work is such as is had from the ruins of old buildings in a low situation, and out of the way of much sun-shine, where there has been no great quantity of fire kept, and especially such as served for the mortar of the walls of stables.

In Prussia, the rubbish of old buildings is built up in thin long walls, sheltered from the weather by straw coverings, and sprinkled with urine of all kinds, for the purpose of generating the salt.

Professor Kidd, of Oxford, has made some curious observations on the production and occasional disappearance of saltpetre on the surface of the lime-stone, of which the Ashmolean laboratory is built, and some other walls in that city. These observations are too long for insertion in this work. He found a clear dry frosty air particularly favourable to the production of saltpetre, and that it disappeared on the approach and during the continuance of a snow storm.

Dr. Ward and some other persons attempted to revive the manufacture of English saltpetre, but were unsuccessful; saltpetre contains no water.

### *Gunpowder.*

The principal consumption of saltpetre is in making gunpowder, the invention of which has totally changed the mode of warfare from that formerly used.

The country people in Russia, Poland, and Tartary, make gunpowder themselves, from private receipts, mixing saltpetre, sulphur, and charcoal dust, in various proportions, and boil them

in water for two or three hours until all the water is evaporated and the composition become very thick; they then take it out of the kettle and dry it in a flat pan placed in the sun, or a warm place, and when nearly dry force it through a sieve, and form it into very small grains. Others grind the composition with water on a slab. The powder thus made is allowed to be equal, if not superior, to that produced by the great manufactories.

The Hon. G. Napier makes the following observations on gunpowder, deduced from a series of experiments when superintending the Royal Laboratory at Woolwich.

The method he has generally adopted for detecting the impurity of nitre, is to drop a strong solution of sugar of lead into a phial of distilled water, saturated with saltpetre; which, if it retained any considerable portion of marine salt or magnesia, assumed a turbid milky appearance. The lunar solution is too powerful a test; but it does not always follow that the purest nitre produces the strongest powder. The best is the Russian; yet the manufacturers in that country are not very solicitous about the magnitude of the crystals, the whiteness of the salt, nor even its freedom from heterogeneous substances; though with us those qualities are accounted essential. In Russia, they seldom refine their nitre more than twice; and it has been found that their saltpetre contains a considerable portion of marine salt and magnesia.

There is reason to believe that powder made with saltpetre oftener than four times refined, is of inferior strength, though probably more durable, than with that which has been only thrice depurated. If the elastic and expansive fluid contained in nitre, partakes at all of a spirituous nature, may not repeated evaporation liberate a portion of it?

It may not be a very improbable deduction to suppose that repeated elixation in part, deprives this salt of that elastic fluid which constitutes the strength of gunpowder. This opinion is strongly corroborated by two well-known facts: first, in purifying a large quantity of nitre, there is a deficiency of weight, after the process, which cannot be accounted for by the weight of the residuum; and, secondly, as great a proportion of saltpetre cannot be extracted from damaged powder as is obtained from serviceable, though originally manufactured with the same quantity of nitre.

Mr. Napier prefers saltpetre, whose crystals are of a moderate size, solid, transparently white, which do not readily break with a crackling noise when gently grasped in the hand, and which, when ignited in a red-hot shovel, do not decrepitate, but melt and consume with an equable and continued inflammation. The first of these symptoms is produced by hasty and imperfect de-

siccation; and the last is a proof that the marine salt has not been entirely separated from the nitre.

If the powder maker refines his nitre himself, he is advised to boil it thrice, carefully skimming off the feculent matter which floats on the surface, filter it through canvas, and leave it to crystallize in leaden or copper vessels, exposed to a free circulation of air in a dry situation, and not in a cold cellar, which is frequently, though erroneously, practised.

The mother-water which oozes from the pans is commonly sprinkled on earth intended for generating saltpetre. Instead of this, were the refiner to add to the mixture a small quantity of wood ashes, and repeat the operation of extracting, he would find it advantageous. He would also save considerably by substituting iron boilers and leaden pans to his copper ones.

On chemical principles, we should prefer charcoal made from wood, containing the greatest quantity of fixed salts, and whose ashes abound with alkaline salts, as such inflames more rapidly, and burns with greater vehemence. Dog-wood (*cornus sanguinea*) and alder (*rhamnus frangula*) are esteemed by powder makers the fittest for their charcoal. Green wood being harder when charred than dry, admits of a more complete comminution, and is consequently better adapted to that intimate combination of the ingredients necessary for the strength and durability of gunpowder.

A manufacturer of gunpowder ought never to use sulphur which he has not purified and sublimed himself. The best method of doing this is by melting it in an iron pot, over a gentle coal-fire which does not blaze, and straining it through a double linen cloth. The operation must be repeated till there appears little or no residuum. When sulphur is bought in a prepared state, it is frequently adulterated with wheat flour, which, in moist or hot climates, readily induces fermentation, and irrecoverably decomposes the powder. Inattention to this circumstance is a principal cause of British gunpowder being less durable now than formerly.

After an accurate examination of powder manufactured according to the most approved practices of Europe and Asia, together with the numerous variations of the chemist, Mr. Napier found it beyond his experience to give a decided preference, as he had seen them all succeed and fail. He therefore recommends that the proprietors of powder mills should manufacture a small quantity of powder from each fresh assortment of materials. In doing this, the following canon, which is borrowed from the French fire-workers, and established by experiments, may be found useful. Begin with 48 ounces of nitre, and nine ounces of charcoal; these will explode without sulphur. In-

crease the quantity of charcoal till the most forcible combination of those two ingredients is discovered, which will commonly happen at between 12 and 16 ounces of charcoal to the 48 ounces of nitre. To this composition let sulphur be added, beginning with half an ounce, till the strongest explosion is found; which will be when the proportion of this ingredient to the above is from 2¾ to 3¼. Finally let the dose of charcoal be diminished, till the composition no longer gains in the eprouvette. This will commonly happen when the proportions of the three materials stand as follow:—nitre, 48 ounces; charcoal, 8½ to 9½; sulphur, 2¾ to 3¼.

The manufacturer, by adopting this method of ascertaining their qualities, however troublesome it at first appears, will in the end be a considerable gainer. There are various opinions respecting the liquid most eligible to moisten the ingredients, during the process of preparing them for the mill. Urine, vinegar, spirit of wine and water, plain water, have severally been recommended for this purpose. Mr. Napier tried them all, without being able to establish any data on which to found a decision. Yet, the volatile nature of spirits, and the heterogeneous matter to be met with in urine and vinegar, seem to point out a preference due to pure water. But, as this is warmly contested, and Mr. Napier's experiments have exhibited no conclusive superiority, he does not seem willing to hazard a determination on the subject. Having, however, procured some powder manufactured at Canton, he analyzed two ounces of it, and after repeating the operation six times, the mean result gave the following proportions:—nitre, 1 Troy ounce, 10 dwts.; charcoal, 6 dwts.; sulphur, 3 dwts. 14 grains. Here is a deficiency in weight of ten grains, probably the consequence of some defect in Mr. Napier's process, which was, first to weigh the powder, next to separate the nitre by solution, evaporation, and filtering. He then weighed the residuum of charcoal and sulphur combined; and lastly he sublimed the sulphur, by a degree of heat not sufficient to inflame the charcoal, which, when weighed, completed the operation, producing the aforesaid result. But as M. Baumé, a French chemist, made a variety of experiments to obtain a total separation of the sulphur from the charcoal, and was never able to effect it, one-fourteenth part remaining united, three grains must be deducted from the charcoal, and added to the sulphur, to give the accurate proportion of the ingredients.

This powder was unusually large grained, not strong, but very durable; it had been made many years when Mr. Napier obtained it; yet there was no visible symptom of decay, the grain being hard, well coloured, and though angular, which form commonly generates dust, it was even sized, and in perfect preservation.

The combining and incorporating the ingredients should be performed, if possible, in clear dry weather;—a lowering sky, and a humid atmosphere, being found inimical to that thorough blending of the materials which ought to precede their being worked in the mill. Stamping mills were formerly used for working gunpowder. Their construction was very simple; it consisted of a large mortar, in which a ponderous wooden pestle, moved by men, by horses, or by water, performed the operation very perfectly, but with obvious danger to the workmen.

In Sweden, and it is believed in Russia, they still continue to stamp the powder, during the first part of the process, and afterwards to roll it under stones. By this means the probability of an explosion is lessened; as the composition is less inflammable in the beginning, than when the materials are more intimately blended.

Since government, alarmed by the frequency of accidents, thought proper to prohibit stamping in the Ordnance-mills, this part of the process has been effected by means of two stone cylinders, moved in a vertical position round a circular trough.

The inferiority of the present practise is visible in its operation on the powder, which has certainly degenerated, both in strength and durability, since the abolition of stamping mills. This may be attributed, first, to neglect in the manufacturer, who is satisfied with working his powder seven or eight hours, instead of twenty-four; and secondly, because the circumferences of two smooth and ponderous stones compress the moist paste into a hard solid cake, over which they make repeated circumvolutions, without contributing much to the incorporation of the ingredients.

Mr. Napier suggests an alteration in the substance and construction of the rollers, to remedy some of the defects in the process of milling. Instead of marble and granite, Mr. Napier proposes that the rollers shall be made of cast iron, as well as the circular trough in which they move; and the periphery of the cylinder be divided into eight equal parts, alternately grooved and plain, with two of the fluted divisions having their grooves transverse, the other two longitudinal. These grooves should be an inch in breadth, and a quarter of an inch in depth, with their angles rounded off. The trough must continue smooth, as in the present practice. The effect proposed from this construction is, that the alternations of the plain and fluted divisions will penetrate the substance of the paste, producing a more intimate connexion and intermixture of the component parts. Or the manufacturer may break the contiguity of the paste by affixing a small but weighty harrow, with copper teeth, to the axis of the roller, and following its direction in the

trough. Iron cylinders are already used in several mills, and the intelligent powder makers allow that accidental explosions are most frequently produced by the collision of chips which break from the edges of stone rollers. The paste, if very moist, may adhere to the grooves; but this will be prevented by the application of oil, in small quantities, to the fluted surfaces. Another alteration is simply working four rollers in the same trough, instead of two.

The process of granulating powder is performed by a horizontal wheel, on which are fixed circular sieves with parchment bottoms, perforated to the largest intended size of the grain. In these sieves the paste is deposited, and with it, in each of them, a small oblate spherical piece of lignum vitæ, which being moved about the sieve by the action of the wheel, breaks the composition and forces it through the parchment bottom, into vessels placed for its reception. But as this operation leaves the powder in grains of various dimensions, it is sorted by being passed through wire screens of progressive sizes.

Gunpowder is commonly dried in a room, three sides of which are furnished with ledged shelves, containing the composition; and the fourth is occupied by a large iron stove which projects into the room, but is heated from without. An amendment has been attempted, by carrying flues round the drying-room fitted with steam: the change has, however, been little, if at all for the better.

The powder returned as unserviceable, which still retained its grain, was usually separated from the dust; and if two drams of it, when tried in the vertical eprouvette, had sufficient strength to project a superincumbent weight of twenty-two pounds to the height of three inches five-tenths, it was again issued for service. But this happening very rarely, a doubt was suggested, that by taking away the dust, the powder was deprived of its principal ingredient. This conjecture was established by repeated experiments in the vertical and mortar eprouvettes; as the dust, though varying in degree, almost always exhibited superior strength to the granulated powder from which it had been separated.

With the assistance of a convex lens, Mr. Napier discovered a new crystallization of the nitre, called by powder-makers the starting of the petre; the minute salts of which, broken by attrition, were converted into that dust which consequently contained the essence of the composition.

When powder is so far damaged as to cake, all attempts to renovate it are nugatory. It should be immediately transferred to the extracting house.

The strength of new powder is not diminished by reducing it to dust, but rather increased. This is a secret well understood

by powder-merchants, who mix dust, in small quantities, with that powder they apprehend will not rise to proof.

It was formerly the practice of government to manufacture their powder as small in the grain as that made at Dantzic or Battel is at present. Whether the large corned powder now used merits a preference is problematical.

In 1782, there were discovered at Purfleet some barrels of very small-grained powder, manufactured by Sir Polycarpus Wharton, surveyor of the ordnance in Charles the Second's reign. It may not be improper to remark, that during this reign, and for some time after, most of the nitre used in England was manufactured at home; and if it be not a mistake, there still exist acts of parliament granting the crown the soil of shambles and slaughter-houses, and the earth under the flooring of stables, bullock-hovels, &c., and also directing the magistrates to have tubs placed in the streets of populous towns for the collection of urine. From these materials there was a sufficiency of nitre extracted to supply the ordinary consumption of government.

Formerly government manufactured three sorts of powder, viz. mortar, cannon, and musket, the first having less saltpetre than the last. The practice should be revived; as sulphur, by its proneness to fermentation, is the ingredient which contributes most to the decomposition of powder. Mr. Napier directed a small quantity to be made from nitre and charcoal, and was surprised to find that fifteen pounds of it projected a thirteen inch shell as far as the best powder composed in the usual manner. Hence, a powder might be made sufficiently strong when used in quantities above ten pounds, with a much less proportion of sulphur than the present practice admits of. In cases where a smaller charge is used, or where a rapid inflammation is required, the usual dose of sulphur is indispensably necessary.

The process of glazing powder is effected by attaching casks, something more than half full, to the axis of a water-wheel; which turning with velocity, the operation is completed in a short time by the friction of the grains against each other. Mr. Napier found from a mean of near six hundred experiments, that glazing of powder reduces its strength about one-fifth, if the powder is good; and nearly a fourth, if of an inferior quality. The proportion of dust separated during the operation is invariably stronger than the glazed powder from which it has been screened.

Government powder, manufactured at Feversham, when received from the mills, is considerably stronger than either Dantzic or Battel shooting powder; and it would continue so were it secluded from the action of the atmosphere. In Dutch men of war, they have an ingenious and safe mechanism for ventilating

their magazines, worthy the imitation of the British navy. In barrelling powder it is of the utmost importance to select dry clear weather; the consequences of inattention to this material point have been oftener felt than suspected by our fleets and armies.

The general preference is due to powder of a moderate size; and somewhat spherical grain. The colour should be a grayish blue, tinged with red, and the texture of the grain firm, but not so hard as to resist a very forcible pressure from the finger against a board. British powder-makers prefer a dark blue colour, and an angular grain, thinking that hue and form susceptible of the readiest inflammation; but numerous experiments convinced Mr. Napier of their mistake.

The strength of powder is frequently impaired by being too precipitately dried. On examining some of the rooms, the crevices of the walls and shelves were filled with flowers of brimstone, sublimed, by the action of the fire, from the surface of the grains, precisely where the greatest proportion of this inflammable principle is required. The acceleration of the drying process has this farther disadvantage, that it leaves the powder moist in the centre of the grain. Such powder, when fresh from the drying-house, will rise to high proof; but being left in the magazine for a month, will lower its strength at least a fourth. Powder should not be proved sooner than two months after being manufactured.

It was formerly the practice to load with large quantities of powder: to demonstrate the absurdity of this practice, the vertical eprouvette was enclosed so as to prevent the escape of uninflamed powder; and after fifty discharges, in each of which two drams were compressed by a weight of twenty-two pounds, three drams and a half of strong and highly inflammable powder were collected. The present charge is a third of the shot's weight for heavy, and a fourth for light artillery: it would still admit of reduction.

Salt of tartar may be introduced as an auxiliary in the composition of gunpowder. It increases the report astonishingly, but is noxious to strength and durability. A powder might be manufactured, a small portion of which would produce a tremendous report, and prevent the unnecessary expenditure of that which is serviceable in the parade of war, where noise only is required. The strength of powder is by no means established by the proof of the vertical eprouvette, unless corroborated by the brass mortar.

It was represented by the Hon. Wellesley Pole, at the House of Commons, in a debate on the Ordnance estimates, in March, 1810, that the excess in the consumption of gunpowder was occasioned by the impossibility of keeping it dry at sea. The

same complaint was again urged by the Hon. Ashley Cooper, in April, 1811, who also stated that the floating magazines were too damp for the stowage of gunpowder. Sir William Congreve, Comptroller of the Royal Laboratory, in a statement of facts, dedicated, by permission, to the Earl of Mulgrave, Master General of the Ordnance, confirms the above, by stating that the gunpowder in the British service was so inferior to that of the enemy, at the conclusion of the American war, that it was the constant subject of complaint both in the navy and army, and as a fact, that when the fleet was disarmed at the termination of that war, in some of the line of battle ships there were not ten barrels fit for service. Since that time the greatest attention has been paid to the manufacture of gunpowder, both at the royal powder mills, and by the private powder-makers, who contract for the supply of government; so that the British gunpowder, when first made, may be ranked with any foreign powder. But, from the impossibility of procuring seasoned wood to make the powder casks, added to the absolute necessity of keeping an immense quantity of powder in the different depôts for the supply of the navy and army, all of which are situated on the sea or river sides, or in floating magazines, and are consequently much exposed to fogs and damps, and from the impossibility of preventing the damp from injuring the gunpowder in the wooden barrels, even in its short transit from one magazine to another, or from being speedily damaged in the magazines of the men of war, either in those casks or in filled cartridges, notwithstanding every precaution, the gunpowder and the cartridges rapidly go to decay; and the advantages which the service should derive by the superior strength of the gunpowder made by and for government, is in a very great degree lessened, if not totally lost to the nation. Sir William Congreve, clearly makes it appear that between the 1st of January, 1789, and 31st of August, 1810, a period of twenty-one years and eight months, government manufactured at their own mills 407,408 barrels of gunpowder; they purchased also of the gunpowder makers, between the 1st of March, 1794, and 31st of August, 1810, a period of sixteen years and six months, 241,980 barrels, making the total of barrels 649,388. The quantity of powder returned back totally unserviceable, because seasoned wood could not be procured to make the barrels, so as to preserve it at sea, amounted to 137,993 barrels. Between the 1st of July, 1790, and the 31st of August, 1810, the quantity returned from the same cause, requiring the process of remaking, by drying, dusting, and mixing old powder with new, amounted to 189,757 barrels, making the quantity of returned gunpowder, because no means could be devised of preserving it, amount to 327,750 barrels.

This calculation proves, beyond the possibility of doubt, that at no part of the above period could it be asserted, as a fact, that any one ship, after being a length of time at sea, was provided with a sufficient quantity of effective gunpowder.

It is presumed, including all the attendant expenses of drying houses, &c., that gunpowder made by government costs infinitely more than it does at the private mills. But supposing each barrel of powder was to cost 8l. exclusive of copper hoops, sixty thousand barrels, the quantity stated by the Hon. Wellesley Pole to be annually required, would amount to 480,000l. per annum, one-fourth part of which, at the very lowest, may be annually saved by adopting copper barrels.

The following is the usual proportions of ingredients in the powder now manufactured in England and France.

| | Saltpetre. | Charcoal. | Sulphur. |
|---|---|---|---|
| Common English powder - - | 75 | 12½ | 12½ |
| Shooting powder - - - - | 78 | 12 | 10 |
| or, - - - - - | 76 | 15 | 9 |
| Powder for blasting mines and quarries | 65 | 15 | 20 |
| M. Bouchet's patent powder - - | 78 | 12⅞ | 9⅛ |

The shooting powder is glazed by the grains being rubbed one against another, in a barrel: the quantity of saltpetre and charcoal in it is large, in order to ensure its quick action.

Miners' powder is similar to the old mortar powder, and has more sulphur and less saltpetre, because the certainty of its operation is of more consequence than the swiftness.

M. Bouchet's powder is now used by the French government: it is very small, and close grained, so that a litre measure weighs 905 French grammes; whereas, the same measure of the best Dartford powder weighed only 857; the French government now requires this compactness in their powder.

### *Fire Works.*

A variety of compositions are employed for the purpose of giving particular appearances to flame, and to accelerate as well as retard the combustion, of the mixture of saltpetre with combustible matters.

What is denominated brilliant fire, (of which there were several kinds,) although partaking in a great measure of the character of the Chinese fire, differs from it, nevertheless, in an essential particular. Besides the usual substances which enter into the composition of brilliant fire, it is now known, and the fact is sufficiently corroborated, that what is called iron sand by the Chinese, which imparts that particular character to their fire, is no other than cast, crude, or pig iron reduced to the state of fine grains.

The cast iron used for this purpose is old iron pots, which they beat into grains not larger than mustard seed; these they separate into sizes, or numbers, in the manner of assorting shot, by means of sieves.

Both iron filings and granulated cast iron have been used in the rocket composition, not only for honorary rockets, but also

occasionally for signal rockets. To prevent the iron from rusting, some have suggested immersing the grains of iron in melted sulphur, which is almost as injurious, owing to the gradual formation of the sulphate of iron, and others have recommended the use of a few drops of oil, and agitating the filings or grains so as to receive a portion of it.

Of the rockets into the composition of which iron sand enters, there are two; one producing a red, and the other a white fire. The proportions of the different ingredients for such rockets, from 12 to 36 pounds, are as follows—

*For Red Chinese Fire.*

| Calibres. Pounds. | Saltpetre. Avoir. pounds. | Sulphur. Ounces. | Charcoal. Ounces. | Cast iron. Ounces. |
|---|---|---|---|---|
| 12 to 15 | 1 | 3 | 4 | 7 |
| 18 to 21 | 1 | 3 | 5 | 7½ |
| 24 to 36 | 1 | 4 | 6 | 8 |

*For White Chinese Fire.*

| Calibres. Pounds. | Saltpetre. Pounds. | Meal powder. Ounces. | Charcoal. Ounces. | Cast iron. Ounces. |
|---|---|---|---|---|
| 12 to 15 | 1 | 12 | 7½ | 12 |
| 18 to 21 | 1 | 11 | 8 | 11½ |
| 24 to 36 | 1 | 11 | 8½ | 12 |

Although the iron is ignited by the combustion of the composition, the combustion of the iron itself does not take place within the tube or only in part, but requires the oxygen of the atmosphere; for the greatest brilliancy of the fire is actually in the air, where the ignited and minutely divided iron is acted upon by the oxygen gas of the atmosphere.

The mixture of the sulphur and iron should be moistened with spirit of wine, as water would rust the iron.

Certain compositions, commonly denominated white fire, are used in cases, and give motion to wheels and the like, the motion is on the rocket principle, and depends on the gaseous products of the inflamed matter acting against the resisting medium, namely, the atmosphere. Chinese fire, however, possesses, in this respect, but little force, and will not turn a wheel; hence, when it is used in rotatory works, it must be accompanied with two or more jets or cases of white fire.

With regard to the preparations of Chinese fire, which are said to surpass even those of the Chinese, the following are the most perfect:—

*Composition of Chinese Fire for calibres under ten-twelfths of an Inch.*—16 ounces each of meal-powder and saltpetre, 4 each of sulphur and charcoal, and 14 of cast-iron.

*Another.*—16 ounces of meal-powder, 3 each of sulphur and charcoal, and 7 of cast-iron.

*Another, for Palm-Trees and Cascades.*—12 ounces of saltpetre, 16 of meal-powder, 8 of sulphur, 4 of charcoal, and 10 of cast-iron.

*Another, White Fire, for calibres of eight-twelfths and ten-twelfths of an Inch.*—8 ounces of sulphur, 16 each of meal-powder and saltpetre, and 12 of cast-iron.

*Another, for Gerbes of ten and eleven-twelfths and one Inch calibre.*—1 ounce each of saltpetre, sulphur, and charcoal, 8 each of meal-powder and cast-iron.

What are denominated fire-jets or fire-spouts, are cases charged solid with particular compositions. These jets have a calibre of one-third of an inch to one inch and a third in interior diame-

ter. They are seven or eight diameters in length, and are charged with the particular composition, driving each charge with twenty blows of a mallet. The first charge is the ordinary fire composition. Fire-jets are calculated for turning as well as for fixed pieces.

*Common Fire, for calibres of one-third of an Inch.*—16 ounces of meal-powder, and 3 of charcoal.

*Common Fire, for calibres of five-twelfths to half an Inch.*—16 ounces of meal-powder, and $3\frac{1}{4}$ of charcoal.

*Common Fire, for calibres above half an Inch.*—16 ounces of meal-powder, and 4 of charcoal.

*Brilliant Fire, for ordinary calibres.*—16 ounces of meal-powder, and 4 of filings of iron.

*Another, more beautiful.*—16 ounces of meal-powder, and 4 of filings of steel.

*Another, more brilliant, for any calibre.*—18 ounces of meal-powder, 2 of saltpetre, and 5 of filings of steel.

*Brilliant Fire, very clear for any calibre.*—16 ounces of meal-powder, and 3 of filings of needles.

*Silver Rain, for calibres above two-thirds of an Inch.*—16 ounces of meal-powder, 1 each of saltpetre and sulphur, and $4\frac{1}{4}$ of filings of fine steel.

*Grand Jessamin, for any calibre.*—16 ounces of meal-powder, 1 each of saltpetre and sulphur, and 6 of filings of spring steel.

*Small Jessamin, for any calibre.*—16 ounces of meal-powder, 1 each of saltpetre and sulphur, and 5 of filings of steel.

*White Fire, for any calibre.*—16 ounces of meal-powder, 8 of saltpetre, and 2 of sulphur.

*White Fire, for any calibre.*—16 ounces of meal-powder, and 3 of sulphur.

*Blue Fire, for Parasols and cascades.*—8 ounces of meal-powder, 4 of saltpetre, and 6 each of sulphur and zinc.

*Another Blue Fire, for calibres of half an Inch and upwards.*—8 ounces of saltpetre, 4 each of meal-powder and sulphur, and 17 of zinc.

The cases charged with these compositions are only employed for furnishing the centre of some pieces, the movement of which depends on other cases; as these, having no projectile force, would not produce motion.

*Blue Fire, for any calibre.*—16 ounces of meal-powder, 2 of saltpetre, and 8 of sulphur.

*Radiant Fire, for any calibre.*—16 ounces of meal-powder, and 3 of pin-dust.

*Green Fire for any calibre.*—16 ounces of meal-powder, and $3\frac{1}{8}$th of filings of copper.

*Aurora Fire, for any calibre.*—16 ounces of meal-powder, $3\frac{1}{8}$th of brass powder.

*Italian Roses, or fixed Stars.*—2 ounces of meal-powder, 4 of saltpetre, and 1 of sulphur.

*Another for the same.*—12 ounces of meal-powder, 16 of saltpetre, 10 of sulphur, and 1 of crude antimony.

The forms which may be given to the flame of gunpowder, or to the substances which compose it, either by increasing or retarding its combustion, or by changing the appearance of the flame, giving it the form of jets, stars, rain, &c. are so numerous, that a knowledge of these changes and variations is considered highly important to the practical fire-worker. For instance, in the composition of fire-works, oak charcoal, and pit-coal, will give the appearance of rain.

The following is one of the formula:—8 ounces of saltpetre, 4 of sulphur, 16 of meal-powder, 2½ each of oak charcoal and pit-coal.

Another composition, intended for the same purpose, is similar to the Chinese fire, but contains a large proportion of powdered cast-iron.

In the spur fire, so called from its spark resembling the round of a spur, used principally in theatres, the particular appearance which characterizes it from other fires, is imparted to it simply by lamp-black.

The composition is:—4½ pounds of saltpetre, 2 of sulphur, and 1½ of lamp-black.

The red fire, used for theatrical purposes, is made from forty parts of dry nitrate of strontian, thirteen parts of finely-powdered sulphur, five parts of chlorate, or oxymuriate of potash, and four parts of sulphuret of antimony, mixed intimately in a mortar; but the chlorate of potasse must be powdered separately. A little orpiment is sometimes added, and if the fire should burn dim, a small quantity of powdered charcoal is added.

The portable fire-works made in miniature, and exhibited in rooms, or close apartments, are much of the same nature as already described.

Other compositions are made, as serpents, crackers, stars, Roman-candles, rocket-stars, variously coloured fire-rains, white, blue, and yellow illumination, port-fires, &c. which show that the colour and appearance of flame may be modified with almost as many variations as the mixture of pigments employed by the painters.

Bengal lights, although in some recipes orpiment is added, owe their particular characteristic to the presence of antimony. The preparation was kept secret for some time.

The true formula is the following:—3 pounds of saltpetre, 13¾ ounces of sulphur, and 7¼ of sulphuret of antimony.

The composition is not used in cases, but is put into earthen vessels, usually shallow, and as broad as they are high. A small quantity of meal-powder is scattered over the surface, and a match is inserted. Pots, thus prepared, are covered with paper or parchment, to prevent the access of moisture, which is removed before the composition is inflamed.

Blue lights, or blue fire, is a preparation in which zinc and sulphur, or sulphur alone, are used. The particular colour is communicated by the zinc and sulphur.

The most perfect blue light is made as follows:—4 parts of meal-powder, 2 (or 8) of saltpetre, 3 (or 4) of sulphur, and 3 (or 17) of zinc filings.

The representation of cascades and parasols, are made with the above or similar compositions, as already noticed, but the ordinary blue light, used sometimes for signals, and adapted to any calibre of a case, is composed of sixteen parts of meal-powder, two parts of saltpetre, and eight parts of sulphur.

Brass is added in the sparkling and green fire. To prepare which, about three parts of brass filings are mixed with sixteen parts of meal-powder.

The amber lights are constituted of amber and meal-powder, in the proportion of three of the former to nine of the latter.

Verdigris and antimony are frequently joined to produce a green colour.

For the green match for ciphers, devices, and decorations, one pound of sulphur is melted, one ounce of powdered verdigris, and half an ounce of crude antimony are then added: cotton, loosely twisted, is soaked in the mixture when melted. When used, it is fastened to wire, and the wire is bent into the shape required. It is primed with a mixture of meal-powder and spirit of wine, and a quick match is tied along the whole length, so that the fire may communicate to every part at the same time.

A strong decoction of jujubes treated with sulphur, imparts to cotton the property of burning with a violet-coloured flame.

Sulphur alone, or zinc and sulphur, gives a blue device.

More attention has been paid to rocket compositions than to any other. The formulæ are, therefore, numerous on the subject.

The following are given as the most approved:—

For Summer.—17 ounces of saltpetre, 3½ of sulphur, 1½ of meal-powder, and 8 of oak charcoal: or, 16 ounces of saltpetre, 4 of sulphur, and 7½ of charcoal.

For Winter.—17 ounces of saltpetre, 3 of sulphur, 4 of meal-powder, and 8 of oak charcoal: or, 44 ounces of saltpetre, 4 of sulphur, and 16 of charcoal: or, 16 of saltpetre, 2¼ of sulphur, and 6 of charcoal: or, 3 ounces of sulphur, 20 of saltpetre, and 8½ of charcoal.

For rockets of honour, either cast-iron or antimony are used.

The Chinese composition is the following:—5 ounces of saltpetre, 1½ of sulphur, 1 of meal-powder, and 2½ each of cast-iron and charcoal. The charcoal is not to be powdered very fine, as the fine dust is not used, except for small works.

M. Bigot's formula, for the same purpose, is:—2 parts of meal-powder, 10 of saltpetre, 3½ of sulphur, 5 of charcoal, and 5 of powdered cast-iron. He has also given another composition, consisting of 16 parts of saltpetre, 4 of sulphur, 9 of charcoal, and 2 of crude antimony.

The composition of the Congreve rockets is supposed to differ from the ordinary kind in many essential particulars: but General de Grave transmitted to Paris a Congreve rocket found on the French coast. The case was made of gray paper, and painted. The largest sort is usually made of sheet iron. The inflammable matter was of a yellowish gray colour, and the sulphur was distinguished with the naked eye. It burnt with a quick flame, and exhaled sulphuric acid gas. The composition was analysed by Gay Lussac, who found it to contain 720 ounces of saltpetre, 16 of charcoal, and 234 of sulphur. Gay Lussac, after determining the proportions, made a composition of a similar kind, and charged a case with it which had the same properties as the English rocket. The proportion of charcoal seems too small.

The art of representing figures in fire, consists in mixing sulphur with starch into a paste with water, and covering the figure with the mixture, observing, previously, to coat it with clay or plaster. While moist, the coat of sulphur and starch is sprinkled over with gunpowder. When dry, matches are arranged about it, so that the fire may speedily communicate on all sides. Garlands, festoons, and other ornaments, may be represented in this manner, using such compositions as produce differently-coloured fires. In connexion with this, cases of one-third of an inch in diameter, and two and a half inches in length, may be employed, charging them with different compositions.

These would produce an undulating fire. The charge may consist of Chinese fire, formed for this purpose of one pound of gunpowder, two ounces of sulphur, and five ounces of very fine cast-iron sand, or of ancient fire, which is composed of one pound of meal-powder, and two ounces of charcoal, or of brilliant fire, made of four ounces of iron filings, and one pound of gunpowder. To these respective charges, the addition of sparks may be made, by using, at the same time, fir or poplar saw-dust, &c., previously soaked in a saturated solution of saltpetre, and, when nearly dry, sprinkled with sulphur.

Bearded rockets are sometimes employed for the purpose of producing undulations, filamentous appearances, &c., in the atmosphere, resembling frizzled hair, which terminate in a shower of fire.

These are quills filled with the usual rocket composition, and primed with a little moist gunpowder, both to keep in the composition, and serve as a match. A rocket, charged in the usual manner, and loaded in its conical cap, or head, in the same way as with stars, serpents, and crackers, would so disperse these quills on the termination of its flight, as to produce in the atmosphere the appearance we have mentioned.

The following compositions are much used in warfare:

*Fusees for Shells.*—3¼ pounds of saltpetre, one of sulphur, and 2¾ of meal gunpowder, well mixed, and closely rammed in the fusee.

*Cotton Quick-Match.*—1¾ pound of cotton, 1½ of saltpetre, 10 of isinglass jelly, 10 of meal-powder, 2 quarts of spirit of wine, and three of water.

*Worsted Quick-Match.*—10 ounces of worsted, 10 of meal-powder, 3 pints each spirit of wine and water, and half a pint of isinglass jelly.

*Kitt, to rub over Carcasses; being a kind of Greek Fire.*—9 pounds of rosin, 6 each of pitch and bees'-wax, and 1 of tallow, or, 21 pounds of pitch, 14 each of rosin and bees'-wax, and 1 of tallow: or, 4 pounds of pitch, 2 each of tallow, bees'-wax, and chopped flax.

*Composition to fill Carcasses.*—10 pounds 5 ounces of corned powder, 4 pounds 2 ounces of pitch, 2 pounds 1 ounce of saltpetre, 1 pound of tallow.

*Port Fire, to fire Great Guns.*—6 pounds of saltpetre, 2 of sulphur, 1 of meal-powder, well mixed, and closely rammed in the cases.

*Stopped Port Fire.*—4 pounds of saltpetre, 1½ of sulphur, and 2½ of meal-powder, to be moistened with linseed oil, and stopped in the case with a wooden drift.

*Composition for Quick Match.*—6 pounds 6 ounces of saltpetre, 8 pounds of meal-powder, 1 gallon each of vinegar and spirit of wine, and 4 of water.

*Trunk Fire, for Fire Ships.*—8 pounds of meal-powder, 4 of saltpetre, and 2 of sulphur.

*Greek Fire, for dipping Stores in a Fire-Ship.*—40 pounds of pitch, 30 each of rosin and sulphur, 10 of tallow, and 2 gallons of tar.

*Smoke Balls, to drive Men from between Decks, or hollow Casemates.*—Melt 4 pounds of pitch and 1 of tallow, in a pan set in a copper of boiling water, and add 10 pounds of corned powder, and 1 of saltpetre. Fill the shell a quarter full with this composition, then put in a little of a mixture of 2 pounds of sulphur with 3 of pit-coal; proceed to fill the shell half full, and then put in more of the sulphur and pit-coal; and the same when the shell is three-quarters filled.

Dr. Mac Culloch, in an exeellent paper on the Greek fire, attempts to show that there were two kinds of it; one of which contained saltpetrè, and was analogous to the modern rocket, except that it had no projectile force, and required to be thrown by artillery, either meehanical or chemical, like the modern squibs. The other kind of Greek fire was a resinous composition, in which naptha formed a prineipal ingredient.

The modern carcass is a combination of the two; the nitrous composition being used to fill the body, while its outside is payed over with the rcsinous composition, or kitt: the approaeh to the carcass, to extinguish it, is rendered dangerous, by the loaded pistol-barrels which are inserted in the charge, and directed different ways.

Dr. Mae Culloch seems to think that an oil, like naptha, could not be advantageously used in mixture with powder or saltpetre. It appears, however, from the Military Discipline of Gerat Barry, an Irish captain in the Spanish service, in 1634, that for entering breaches, or ships, or to break into an array of pikemen in a narrow place, they then used fire-trunks, for which he gives this receipt.

Six parts of musket powder, 4 of sulphur, 3 of saltpetre, 1 each, of sal ammoniae, pounded glass, and of camphire, 2 of rosin, and a half part of quicksilver, well mixed together, and then beat up with oil of juniper berries, or oil of petroleum, (by which naptha is no doubt meant,) and spirit of wine. The trunks or wooden cases bound round with marline, were charged in alternate layers with this composition and gunpowder; and the quantity of three musket charges of powder was placed at the bottom of the trunk, which was fastened to a pike staff. He says the flame of these trunks will reaeh twelve feet or more.

## *Oxymuriate of Potasse.*

This salt has been recently named *chlorate of potasse*, as it is produced by passing oxymuriatic aeid gas, otherwise called chlorine, through potasse water.

In general the subcarbonate of potasse water is made of American potash, which is purified as much as possible, by allowing it to remain for some days in stone-ware vessels, before pouring it off for use; and it should be of the strength of 30 to 35 of Baumé, according to the temperature of the season. After

the apparatus has been made ready, and the joinings carefully luted, a quantity of muriatic acid is poured into each of the bodies, which is repeated when the oxymuriatic acid gas ceases to come over: and this is continued until the acid is consumed; as the strength of the acid can be known pretty accurately, the two are proportioned to one another by the operator, and he pours no more muriatic acid into the bodies than will produce oxymuriatic acid gas enough to answer this purpose. When all the acid has been added, and the gas has nearly ceased to pass over, heat is applied, but very gradually, and without interruption, till the tubes of communication become heated, and the liquid in the intermediate bottle is discoloured, and augmented in quantity. During the operation, care must be taken to keep the pipes clear of obstruction, and to notice the height of the liquid in the safety pipes, or the operator will be much incommoded by the emission of the chlorine, or oxymuriatic acid gass; the alkaline solution, into which the gas is conveyed, grows at first thick, owing to the silica contained in the potash, which is precipitated as the saturation is effected; afterwards an effervescence takes place, which increases as the operation is continued, and crystals of chlorate or oxymuriate of potash are deposited in brilliant scales. In some laboratories the solution of potash is filtered after the operation has been begun, in order to separate the silica, which is almost wholly deposited at the commencement. This, however, is an inconvenient method, and, in general, it is better to wait till the operation is over, when, after having drained the liquid off the chlorate and the silica, boiling water is poured on them, which is then filtered, and the chlorate or oxymuriate will crystallize as the water cools.

This salt has the property, when mixed with combustibles of decomposing them with a violent detonation. On this account Berthollet proposed to use it in making gunpowder, and a manufactory was begun at Essonne, in France but the very first attempt at making it cost two persons their lives, the project was immediately abandoned, and has never since been revived. It, however forms the basis of Mr. Forsyth's percussion powder, which is now employed as a priming for fowling pieces, and of the matches for procuring instantaneous light; it is also used to make oxygen gas.

### *Javelle Bleaching Liquor.*

A manufactory at Javelle sold a particular liquor, which they called Javelle ley, and which had the property of bleaching cloth, by an immersion of some hours only.

The following are the proportions which yielded a liquor similar to Javelle ley: two pounds and a half of common salt, two pounds of sulphuric acid, three quarters of a pound of black manganese, and, in the vessel where the gas is to be condensed, two gallons of water, and five pounds of potash, which

should be dissolved in the water. The Javelle liquor has a somewhat reddish appearance, occasioned by a small quantity of manganese, which either passes in the distillation, because an intermediate vessel is not used, or exists in the potash, most kinds of which contain it.

This liquor may be diluted with from ten to twelve parts of water; and, after this, it bleaches more speedily than the liquor itself; but there is formed a portion of oxymuriate of potash, which is useless for bleaching.

Chlorate, or oxymuriate of potasse, mixed with muriatic acid, and diluted with water, forms an extemporaneous bleaching liquid, of this kind, which may be instantly made; for it is only necessary to put a few grains of the oxymuriate into a tea-spoonful of spirit of salt, and dilute it with water, and it will remove almost all kinds of spots from linen, except those made by oily or greasy substances.

### *Acetate of Potasse.*

This was called, by the medical faculty, *foliated earth of tartar*, and *diuretic salt;* it was formerly made from distilled, or even common vinegar, which rendered it extremely difficult to procure the salt of a pure white colour.

It is now generally made, by dissolving a Troy pound of purified pearl-ash in two pints of water, and pouring into this solution a sufficient quantity of purified pyroligneous acid, until an effervescence is no longer produced; of which, according to Mr. Phillips, it will require about 25½ ounces of the acid ordered by the College of Physicians. They order the liquid to be evaporated until the surface skins over; and these skins, as they form, to be taken off and dried between white filtering paper.

The manufacturers generally filter the liquid twice; first as soon as the acid and alkali are mixed, and then, again, when the liquid is evaporated nearly to the consistence of a syrup, and cooled. They then evaporate the filtered solution, by small portions at a time, in a large pan; and, as the solution skins over, the skins are brought by a spatula to the side of the pan to dry.

When acetate of potasse is made with vinegar, although it is distilled, or with unpurified pyroligneous acid, the alkali should be added to the acid; and it will be necessary, after the skins or exfoliations are procured, to blanch them, by melting them in a gentle heat, adding a little bone-black, then pouring on the cooled mass distilled water, to re-dissolve the salt, replacing the acid which has been driven off by the heat, with some purified acid, and again evaporating the liquid, and separating the exfoliations as they form.

This salt is so apt to grow moist, and even run to water, in the air, or in stoppered bottles, that it should be kept in small well-corked phials, and the corks rosined.

The composition of *acetas kalicus*, according to Berzelius, is K: A-², and its weight 2,462,000. Dr. Thomson, who crystallized his salt in a vacuum over oil of vitriol, makes it K· A-+ 2 H·, and its weight 14,500; from which, if the water of crystallization be taken, the weight of the dry salt will be 12,250.

### *Soluble Tartar.*

This salt is the *tartarate of potasse* of the theoretical chemists, and present medical faculty.

It is made by dissolving sixteen pounds of purified pearl-ash in sixteen gallons of water, and adding cream of tartar until it no longer produces an effervescence, which will take about thirty-six pounds. The solution is then filtered through paper, boiled to a skin, and then set by to crystallize as it cools.

This is used largely as a medicine: the practising apothecaries frequently do not take the trouble to make it, or pay the price of it, but keep the salts mixed in the proper proportions, and make up the prescriptions with this mixed powder.

This *tartaras kalicus* of Berzelius, is equal to K: T-², or 2,848,810: Dr. Thomson makes it K· T-, or 14,250, when dry, but the crystals contain two atoms of water of crystallization.

### *Oxalate of Potasse.*

This salt is easily prepared by saturating carbonate of potasse-water with liquid oxalic acid.

It is used to discover the presence of lime in mineral waters, or acid solutions.

Berzelius states the composition of *oxalas kalicus* as K: O-², and its weight as 2,083,370: Dr. Thomson as K· O-, or 10,500; the crystals retain one atom of water.

### *Triple Prussiate of Potasse.*

This salt was first formed by Dr. Macquer, and called by him *phlogisticated alkali*, and by others *Prussian alkali*. In the old French nomenclature of Lavoisier, it was the *triple prussiate of potasse*. M. Porret calls it *ferruretted chyazate of potasse*, which Dr. Thomson has shortened to *ferro chyazate of potasse;* in the new French nomenclature of Gay Lussac, it is the *hydro-ferro cyanate of potasse*. It is also called the *ferro prussiate of potasse*.

This many and long-named salt is thus made:—Two pounds good pearl-ash, and five of hoofs and horns, are flung into a slightly red-hot iron pot set in a furnace. The mixture is stirred well with a flat iron paddle, and as it calcines, it will gradually assume a pasty form, during which transition it must be kept stirred about without any sparing of manual labour. When the cessation of the fetid animal vapours shows the calcination is finished, the pasty mass is taken out with an iron ladle.

If this were thrown, while hot, into water, some of the prussic acid would be converted into ammonia, and of course the usual product diminished; it is, therefore, allowed to cool, and dissolved in water. The solution is then clarified by filtration or subsidence, and evaporated until, on cooling, yellow crystals of the ferro-prussiate of potash are produced. These crystals are separated, re-dissolved in hot water, and by allowing the so-

lution to cool very slowly, large and very regular crystals will be obtained.

The original method of making triple prussiate of potasse, and which is still used, is, by acting on Prussian blue with pure carbonate of potasse-water. The blue should be previously digested, at a moderate heat, for an hour or two, in its own weight of oil of vitriol, diluted with five times its weight of water; then filtered, and the sulphuric acid thoroughly washed out by hot water. Successive portions of this blue, thus purified from the alumine, are added to the alkaline solution, as long as its colour is destroyed, or while it continues to change from blue to brown. The liquid is filtered, the slight alkaline excess neutralized with acetic acid, then concentrated by evaporation, and allowed slowly to cool and crystallize.

The triple prussiate of potasse is used to ascertain the presence of metals in waters, and acid solutions. Its composition is not settled, as it is uncertain whether the acid itself contains hydrogen, or is merely a combination of one atom of cyanogen with one of iron, or 2 C Az Fe. Indeed the whole theory of Prussian blue, and the substances obtained from it, has, ever since its discovery, been a riddle, which no chemist has been able to solve.

### *Priming for Percussion Guns.*

A variety of experiments have been made, by Lieutenant Schmidt, on the different powders used as priming for percussion guns.

He found a mixture of 100 grains of oxymuriate of potasse, with 12 of sulphur and 10 of charcoal, to be much preferable to either fulminating silver, or fulminating quicksilver, for priming. It is not so liable to accidental explosion, it leaves behind it less acid matter, and does not corrode the iron so rapidly; and, contrary to what takes place with fulminating quicksilver, its explosion is not followed by a deposition of moisture. The facility and certainty of the explosion is the same in both.

A mixture of 100 grains of chlorate of potash, with 42 of saltpetre, 36 of sulphur, and 14 of lycopodium, is not nearly so efficacious as the first; although this is chiefly a consequence of the ordinary construction of the touch-hole. The best method of filling the copper caps is, to mix up the explosive compound into a thick liquid, with any adhesive solution or tincture, and, by means of a hair pencil, to introduce a large drop of this mixture into the bottom of each cap.

Another preparation for the priming powder for percussion guns, is three drams of regulus of antimony, and one dram of oxymuriate of potasse. On account of the corrosive properties of the oxymuriate of potash, it is adviseable to use the smallest possible quantity that will be certain of ignition; the above ingredient, if well compounded from a percussion powder, will fire with the greatest certainty.

One great objection to the stronger preparations for priming, is the great and sudden corrosion produced after firing; so violent is this, that should the interval between firing much exceed an hour, the touch-hole is not unfrequently completely closed by a strong rust.

## SODA, OR MINERAL ALKALI.

This fixed alkali was confounded with potasse, until Margraaf pointed out the difference. It was distinguished by him as the *alkali of common salt;* on the first introduction of the significant nomenclature, it was called *natron*, but the French chemists altered this to *soda*, by which it is called in South Europe and the British Islands; but the Northern nations retain Bergmann's generic name of *natron* or *natrum*. It has also been called *fossil alkali*, which Dr. Pearson contracted into *fos-alkali*.

Pure soda is obtained by burning sodium in oxygen gas, but is not used.
Soda or natrum is, according to Berzelius, Na:, equal to 781,840; but Thomson makes it only Na· or 4,000.

### *Kelp.*

This is an impure carbonate of soda, which is made from plants which grow on the sea-shores, and generally from those growing between high and low water-marks. All shores are not equally adapted for the production of these plants. On such as are exposed to the ocean, the rolling of the waves, and the fury of the tempests, prevent the plants from taking root. They thrive best in sheltered bays, where the retreat of the tide leaves an extensive surface uncovered, and where the bottom is composed of stones or rocks, to fasten their roots.

Only the plant called *tangle*, and some others which adhere with great force to the rocks, are found to grow on exposed situations. But these are always within the low water-mark of ordinary tides, and can only be procured at the very low ebb of spring tides. They are, however, so strong and substantial, that they will amply reward the labourer for his trouble.

Though the spring be the best season for making kelp, yet, owing to other avocations at that season, it is seldom made except during summer. To prepare the materials for making kelp, the sea-weeds are dried in the same way that hay is made, taking care to let it get as little rain as possible. When dry, it is coiled or stacked up for burning, and the stacks so formed as to exclude rain.

The breadth of the kilns for burning the weeds ought always to be twenty-eight inches. If the kilns be two or three inches narrower, they will not contain a sufficient quantity of stuff to raise a proper heat. Making them wider is still worse; for then some of the stuff in the middle will not be half burnt. With the assigned breadth, they may be extended in length, as far as the quantity of stuff to be burnt may require.

The kilns are commonly made of various lengths, from eight to eighteen feet, and about two and a half feet high. They

are built of stone, and placed sideways to the quarter from which the wind commonly blows. The windward side is covered with green turf; and if the wind be high, it is covered all round with turf as occasion may require.

Some dig a round hole in the earth, and line it with stone. But a considerable proportion of the stuff in such a kiln, remains not completely burnt, and what is left in that state yields no alkali. It is indifferent what kind of fuel is used, provided it be properly set. If it be wood or heath, it is set on end, so as to fill the whole kiln from one end to the other. If heath is used, the top is always put undermost; and the strongest sort that can be got is preferred.

The kiln being thus filled with fuel, some of the driest ware is spread lightly over it, until the whole be covered. Then, if the day appears good, the fire is applied at the end which is farthest from the wind. It is, then, lightly and constantly supplied as it needs, with fresh ware, thrown by the hand, or a pitch-fork, upon every red hole that appears. In calm weather, when it burns slowly, it is lightly fed, that it may get air. If the weather be very calm, the turf-cover is removed from both sides of the kiln. If there be a slight wind, the windward side, at least, is covered; and if the wind should rise, both sides are instantly covered; and again, if high, the covering is doubled as circumstances may require.

During the whole process, every hole that appears is quickly and attentively filled with fresh materials, until the whole of the sea ware is burnt. Then the feeding should stop all at once; and every hole that appears is filled with a fork, from the thickest and least burned portions, until the stuff is seen to soften or melt at the stones of the kiln. This is the most critical period of the whole process, for sometimes, in cold weather, it is apt to freeze or harden on a sudden: to prevent this, it is instantly wrought in the following manner.

The instruments used for this purpose are strong, narrow clads or clatts, with long handles of iron. Before these are applied to the materials, they are previously heated over the flame; for a cold body introduced among the stuff, at this stage of the process, causes what is already prepared or melted, to fly in the face of the workman, or scatter about.

The operation is begun at the corner farthest from the wind, by pressing down a little of the unmelted stuff to the bottom of one of the holes nearest to the stones. If it appear to boil, soften, or melt, more stuff is added, and pressed down as before.

It must then be wrought backwards and forwards, until the mass is brought to a proper consistency. When that is done, this portion should be dropped, and another portion contiguous

to it should be taken and wrought in the same manner, until the whole is finished. Sometimes a portion of the kelp will be found congealed on the sides of the kiln; this is taken off while working, and mixed with the rest, but in such proportion as not to cool the part that is preparing.

But if, when this operation is begun, the materials still continue hard and dry, they are allowed to burn a little longer. When again tried, if they still remain dry like ashes, a little common salt, sprinkled over the whole of the stuff, adds greatly to the force of the fire. If it still continues obstinate, more salt is added; and, if the weather be calm and warm, the kiln is allowed little or no covering on its sides, unless its contents threaten to congeal.

If the salt has not the desired effect, which seldom happens, a little saltpetre is mixed with it, which causes it to burn vigorously: or, if it be very dull, a little flowers of brimstone is added to produce the same effect.

This disagreeable double toil seldom occurs, except in bad weather, or when rain got at the ware while it was drying. Ware that is dirty or soiled, from having grown in confined muddy bays, is also liable to this accident.

When a new burning commences, if much dust and ashes remain from a former burning, the smaller parts are fed into the kiln with the fresh ware or wrack, after it has begun to burn vigorously; and towards the close of the process the largest and hardest parts are placed in a row along the centre of the kiln from end to end. Thus the heat brings the whole into fusion, so as to form kelp. After the kelp is made, it is carefully excluded from air and moisture.

It is esteemed of good quality when, on breaking a piece, it is hard, solid, and has some reddish and light blue shades running through it. When it has none of its peculiar salt taste it is unfit for making ley, though it may be of use to glass-makers.

By dissolving a little of it in water, it can be ascertained whether it is adulterated by sand, mortar, or stones; though it is impossible to make kelp free of some sand and stones, in the ordinary ways of preparing it.

According to Kirwan, 100 pounds of *Mealy's Cunnamara kelp* contains only 3 pounds 475 of pure soda; and the same quantity of *Strangford kelp* only 1 pound and one-fourth.

Chaptal says the *blanquette* or *soude of Aigues mortes*, which is made from various plants growing wild on the sea-shore, as, salicornia Europæa, salsola tragus, atriplex portulaeoides, salsoli kali, and thrift, contains only 3 to 8 pounds of carbonate of soda in 100.

The *vareck*, or *soude of Normandy*, made from sea-weeds, contains scarcely any carbonate of soda, but is a mixture of much of the sulphates of soda and potasse, and of the muriates of the same alkalies, with a little of the iodure of potassium.

### *Barilla.*

The best kind of carbonate of soda is called barilla, from an herb of the same name in Spain that produces it, the mesembryanthemum nodiflorum.

The carbonate of soda made of this plant, makes the best soap, the finest glass, and is the best for bleaching of any other.

Whether or not it would grow in England is not known, as it has, perhaps, never been tried on a large scale; but it would be a considerable improvement where fixed alkalies of all kinds are so valuable a commodity, and so much wanted; for it grows on the same ground with corn of any kind, to which it does no harm, as it is a small annual herb, that does not spread till the corn is ripe or off the ground.

There is another kind of barilla imported from Alexandria, commonly called *rochetta*, procured from the mesembryanthemum Copticum. Some prefer this to the Spanish barilla, especially for making glass.

These two species of barilla contain about 25 pounds to 40 of carbonate of soda in 100 pounds.

The *salicor*, or *soude of Narbonne*, is produced from the salicornia annua, cultivated round about Narbonne: this contains about 14 or fifteen pounds of carbonate of soda in 100 of salicor. An English acre and a quarter yields only a ton of salicor, which produces about 100 pounds of the alkali. The plant grows wild on the shores of England.

### *Natrum or Trona.*

This is imported from Egypt and Africa, in solid masses. They are found on the hedges of pools dried by the summer's sun.

The same kind of mineral alkali is also obtained by evaporating the water of certain lakes in Hungary and America.

This salt differs from kelp and barilla as being principally formed of the sesqui-carbonate of soda.

### *Carbonate of Soda, or Mineral Alkali.*

This salt is the *mild mineral alkali* of the late chemists, and the *sodæ sub-carbonas* of the medical faculty, and is ordered by the College of Physicians to be made by dissolving Spanish barilla in four times its weight of water, filtering, evaporating to half its bulk, and setting it by to crystallize; but this process is too expensive for the manufacturers.

Le Blanc and Dize's process is, to mix 180 pounds each of dry Glauber's salt and chalk with 110 of charcoal, to grind them together, to heat the powder in the side chamber of a reverberatory, stirring the mass every quarter of an hour. The mass becomes pasty, it is then drawn out by hoes into iron

pots: the produce is about 300 pounds, containing about 100 of pure carbonate of soda. Six workmen can make ten parcels, or nearly a ton and a half in twenty-four hours.

Several other processes have been invented, in some of which the spent bark of the tanners have been used instead of charcoal.

Carbonate of soda is also obtained as a secondary product in the manufacturing of mineral yellow from lead.

Several attempts have been made to procure it from common salt; by calcining the salt with charcoal, but without success.

In some manufactories wood vinegar is employed to decompose Glauber's salt.

The process employed is extremely simple. It consists in boiling for a given time, a solution of Glauber's salt with a solution of acetate of lime, prepared with pyroligneous acid. In this operation the sulphuric acid leaves the soda to attach itself to the lime, and at the same time the acetic acid combines with the soda, and forms an acetate of soda: the latter salt being very soluble remains in solution, whilst the sulphate of lime which is difficult of solution is precipitated.

When the operation is considered as finished, the liquor is left to cool, filtered, evaporated to dryness, and the residuum calcined in a furnace made for the purpose; and when the acetate is entirely decomposed, nothing remains but a white substance, the solution of which, in water, needs only to be evaporated to a suitable point to furnish very fine crystals of carbonate of soda.

When the idea of decomposing the sulphate of soda with the vinegar of wood was first conceived, it was thought that this acid might be used unrectified; but it was soon found that the soda obtained from it was not pure, and that, to procure it in the state desired, it was necessary to have recourse to fresh operations, which, of course, rendered the process more complex.

Mr. Hodson has bestowed much attention on this subject, and took out letters patent for the following process.

Having prepared three hundred weight of well-burnt lime, it is slaked with a strong brine, and sprinkled with it until the salt appears to be accumulating on its surface. The lime thus slaked and saturated with salt, must be spread into thin layers, until the evaporation is completed, and then thrown into a reverberating furnace, with a chamber on the side. To this afterwards must be added, three hundred weight of salt, or rock salt in a shelly state, and the whole melted with a strong heat. When this is effected, two hundred weight of gypsum, and two hundred weight of sal enixum, are to be introduced, and

by means of repeated stirring with a hoe, the different materials must be as generally, and as uniformly, distributed as possible.

Two spades full of small coal, coke, or charcoal, must next be thrown into the furnace; and by means of stirring as before, intimately united with the whole mass. This must be repeated at intervals of the space of one quarter of an hour, until two hundred weight of charcoal be consumed; if coal be used, until three hundred weight; if small coal, until four hundred weight be consumed.

The process must then be continued without any farther admixture, with a strong heat, for three or four hours, or more, according to the degree of purity which it is designed the ash should possess. After which the fluid mass is to be extracted by means of the hoe, and when cold, broke up into lumps for use.

In order to obtain mineral alkali from the natural salt of kelp, from soda, and from the residuum of spirit of salt, having previously reduced either of these articles into lumps of about two pounds weight each, about ten hundred weight are thrown into the furnace, with four hundred weight of gypsum, or four hundred weight of soapers' waste. Afterwards, two hundred weight of charcoal are introduced, at intervals, of the space of one quarter of an hour each, and the mass must be continued to be stirred with the rake until the decomposition is effected, which will happen in about ten hours, computing from the commencement of the process.

To obtain mineral alkali from the neutral salts of natron and sal enixum, five hundred weight of natron, or of sal enixum, are thrown into the furnace, with four hundred weight of gypsum, or four hundred weight of soapers' waste. To these are to be added two hundred weight of black ashes, or four hundred weight of salts obtained by evaporation from soapers' leys; all which materials being well united together, two hundred weight of charcoal are added, at intervals, of the space of one quarter of an hour each, and the process continued for about ten hours, computing as before, from the commencement of it.

In obtaining mineral alkali from black ashes, or other salts obtained from soapers' leys, five hundred weight of black ashes, or nine hundred weight of uncalcined salts, are put into the furnace, together with four hundred weight of gypsum, or of soapers' waste. When these materials are completely fluxed, two spades full of charcoal are added, at intervals, of the space of one quarter of an hour each, until two hundred weight of it are introduced. The materials are to be well united by means of the rake, and to remain in the furnace for about eight hours, computing from the commencement of the progress.

Dr. Thomson found that although carbonate of soda is sold in beautiful crystals seven or eight inches long, all the specimens he could procure contained sulphate of soda, and generally in the proportion of two pound in a Cwt. He could not entirely separate this sulphate even by twelve careful crystallizations.

*Carbonas natricus*, according to Berzelius, is Na: C: $^{2}$ + 20 (H·H) equal to 3,597,770. Thomson makes it only Na·C: + 10 H·, equal to 18,000, which is the same in effect.

### *Sesqui Carbonate of Soda*

Is obtained, by exposing carbonate of soda water to an atmosphere, or current of carbonic acid gas, as in making bi-carbonate of potasse.

It may be considered as a combination of an atom of carbonate of soda with one of bi-carbonate of soda, or as composed of two atoms of soda with three of carbonic acid and four of water.

It is the *sodæ carbonas* of the medical faculty, and is sold for making soda water.

### *Bi-Carbonate of Soda.*

This is made by forcing carbonic acid gas into strong carbonate of soda water: the crystals cannot be dried, for the least heat drives off a part of the carbonic acid, and converts them into sesqui carbonate of soda.

### *Carbonate of Soda Water*

Is obtained by dissolving carbonate of soda in distilled water.

It is used to discover the presence of lime in mineral waters, and acid solutions containing it. Henry advises it to be kept of the specific gravity of 1·110, as it will then neutralize half its measure of either sulphuric acid at 1·135, of nitric acid at 1·143, or of muriatic acid at 1·074.

### *Caustic Soda.*

This is the *hydrate of soda* of the theoretical chemists, and is prepared from carbonate of soda and quick-lime, in the same manner as the hydrate of potasse.

### *Caustic Soda Water.*

This is made from carbonate of soda, by abstracting the carbonic acid by means of lime, and according to Meyer, substituting in its place the principle of causticity. The manipulation is the same as with potasse.

As almost the only use made of it in laboratories is in examining mineral waters, Dr. Henry advises it to be kept of the specific gravity 1·070; when it will be of the same effective strength as carbonate of soda water at 1·110.

### *Double Soda Water.*

This common summer beverage is prepared by dissolving carbonate of soda in water, two avoirdupois ounces to a wine gallon, and forcing carbonic acid gas into the solution, by the apparatus described under carbonic acid water.

The manufacturers call water impregnated only with carbonic acid gas, *single soda water.*

### *Glauber's Salt.*

This salt is found native in some countries; but in England it is generally made from the residue left in making Glauber's spirit of salt, by saturating the superfluous acid, if necessary, by the addition of soda or lime.

It is also obtained, as a secondary product, in the manufacture of sal ammoniac, from sulphate of ammonia.

The salt is purified, and rendered fit for the market, by solution in water, evaporation, and crystallization. As it falls to powder in the air, a vessel, or layer, of water is usually kept in the vessel in which this salt is stored.

Glauber's salt was much used as a purgative, but Epsom salt is now generally preferred by those who are free agents, so that it is now seldom used, except by the parish poor and plantation slaves. It is also used in glass-making.

The crystals contain no less than ten atoms of water, to one each of acid and alkali, according to Thomson, or 55 parts in 100.

### *Cubic Nitre.*

This is the *nitrate of soda* of theorists. It is obtainable by saturating the mother waters of the saltpetre workers with carbonate of soda, instead of wood-ashes; or by saturating carbonate of soda with nitric acid, and crystallization.

Proust recommends it to the fire-workers, as an economical substitute for saltpetre, burning three times as long.

### *Common Salt.*

This is the *muriate of soda* of the old French nomenclature; the *chloride of sodium* of the newest French nomenclature; and the *murias natricus* of Berzelius, and the northern nations.

Common salt may be distinguished into three kinds, viz. 1, rock or native salt; 2, bay-salt; and, 3, white salt; the two former being of a gray colour.

Rock-salt, or native salt, is dug out of the earth, and has not undergone any artificial preparation. Under bay-salt may be ranked all kinds of common salt extracted from the water, in which it is dissolved, by means of the sun's heat and the operation of the air; whether the water, from which it is extracted, be sea-water, or natural brine drawn from wells and springs, or salt water stagnating in ponds and lakes. White salt, or boiled salt, includes all kinds of common salt extracted by boiling from the water in which it was dissolved.

*Rock-salt* is dug at Namptwich, in Cheshire, and many other places. As it forms very thick beds, the miners use, in general, a peculiar kind of excavation, different from that of the pursuit of metallic veins by galleries. In fact, the mine is a

hollow parabolic conoid, with a narrow entrance by a well at the top.

Fig. 111, represents a section of the salt-mine at Visachna, on the south-west of the Carpathian mountains, where the bed of salt, which is covered with several strata of clay and sand, has been already penetrated to the depth of about six hundred feet; it contains within it thin veins of the same black fat bituminous clay, containing sulphate of lime, that forms the immediate covering of the bed of salt.

*A*, the shaft by which it is drawn out.

*B*, the shaft through which the workmen pass up and down, by means of a ladder.

*C*, a shaft that conducts the rain-water into the gallery, *e*.

*D*, a shaft that conducts the rain-water into the drain, *f*.

*E*, two circular galleries surrounding the shafts, *a* and *c*, to collect the water that drains through the over-lying strata of clay, and conduct it into the drain, *f*.

*F*, a drain to carry off the water.

*G*, the conoid space from whence the salt has been worked.

*H*, pieces of timber driven into the bed of salt, and supporting all the wood work of the shafts: these timbers have sheep-skins nailed on them to preserve them from wet.

*I*, bags in which the salt is drawn up to dry.

*K*, cuts in the bed for extracting the salt in oblong squares.

*L*, blocks of salt ready to be drawn up.

Rock-salt, ground, is used in many countries; but in England, and some other kingdoms, the revenue laws prohibit its use, except in particular cases, under very severe penalties.

*Bay-salt* of every kind is prepared without artificial heat, and by only exposing the brine, in shallow basins of clay, to the action of the sun and air, by which in proportion to the strength of the brine, and to the different temperature of climate and season, the salt crystallizes spontaneously, and is generally in the form of hollow square pyramids, or hoppers, formed of cubes.

The basins in which bay-salt is prepared, consist of two parts:—1, a large reservoir, which generally communicates with the sea by means of a sluice. In this the salt water is kept for some days, in order to settle and become quite clear before it is let into the proper brine-pits.

2. The brine-pits are a number of very shallow basins, only a few inches deep, with raised paths between them for the workmen to let in the salt-water, and rake out the crystals of salt as they form. These basins communicate with one another by cuts through the paths, which are stopped with a ridge of clay.

Though salt is made in warm climates with the greatest ease, and at the least expense, by the heat of the sun, after the methods already described, yet, in several countries, where bay-salt might be conveniently made, they prepare all their salt by means of fires.

An erroneous opinion long prevailed in England, that the heat of the sun was not sufficiently intense, even in the summer season, to reduce sea water, or brine, into bay-salt. And all arguments would probably have been insufficient to remove this pre-

Fig. III.

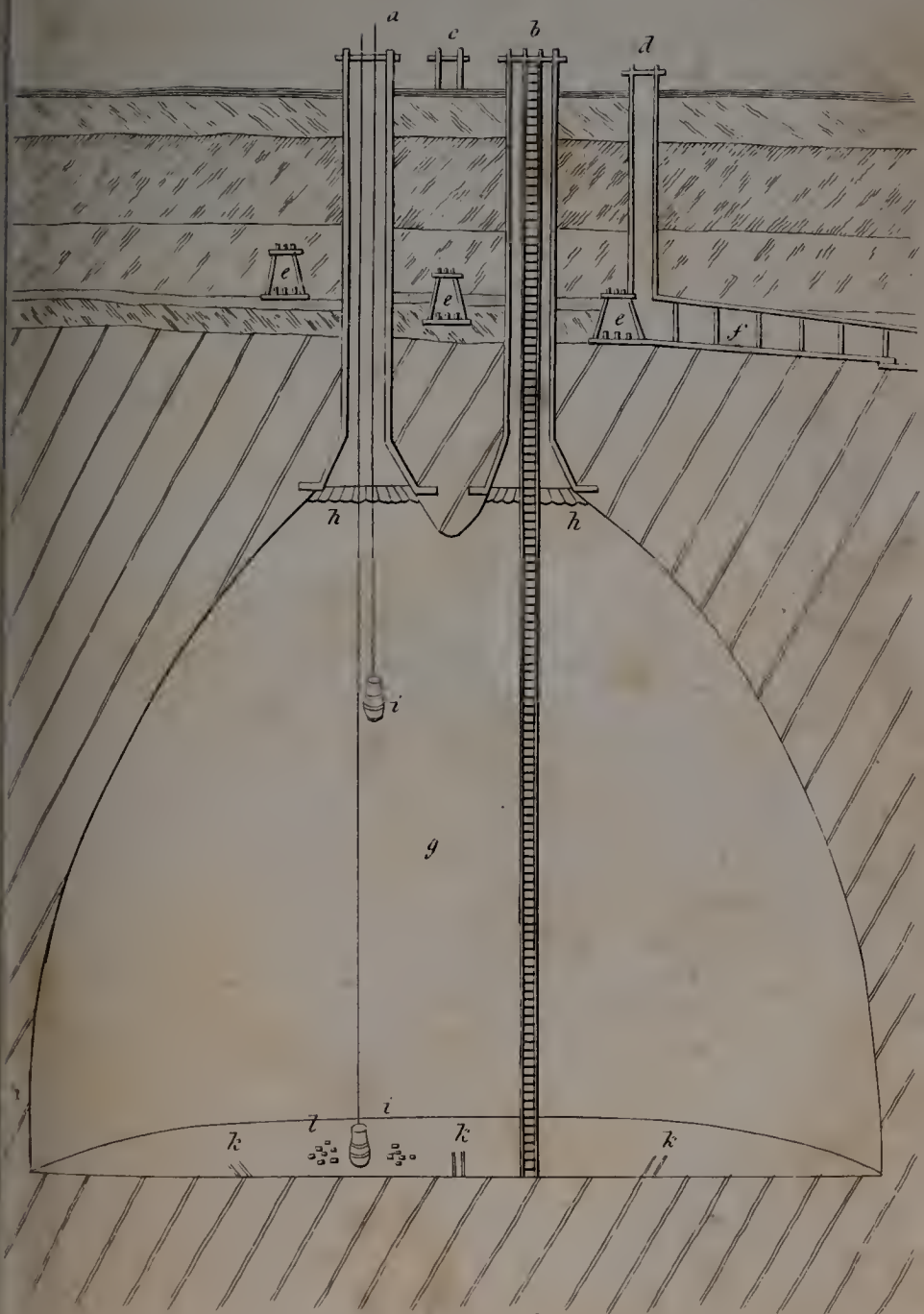
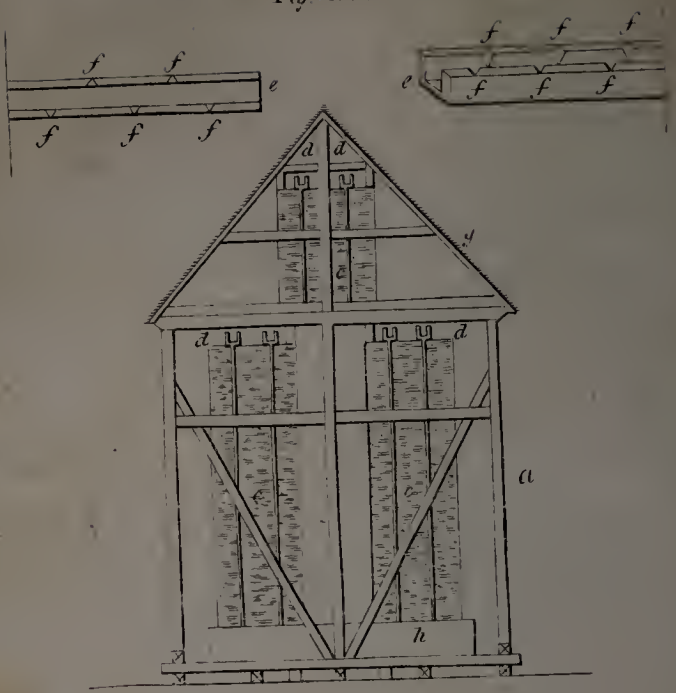
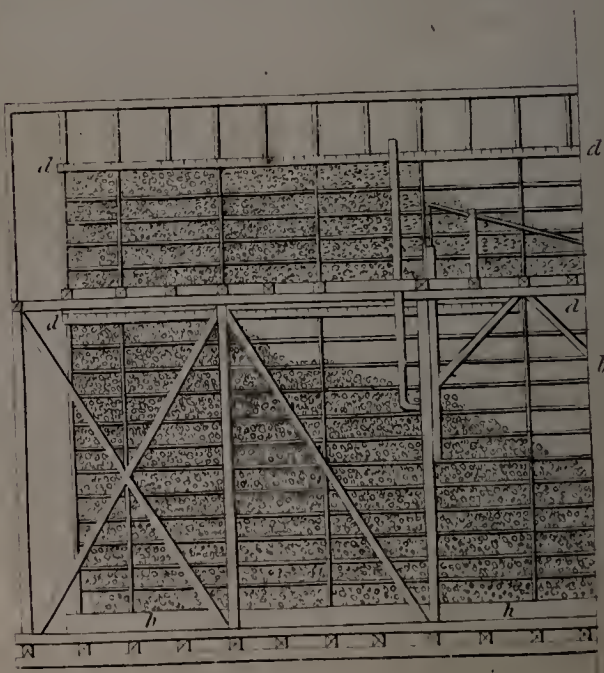


Fig. 112.




0 5 10 15 20 Fathoms

judice from the English, had not the contrary been fully proved by experiments, which were first accidentally made in Hampshire. However, the method of making salt by boiling still continues to be practised in Britain: as the salt so prepared is preferable to bay salt for table use; and, when prepared after a particular manner, is fully equal, or preferable, to common bay salt, even for curing provisions.

The natural brine-springs, and especially the water of the sea, being very weak, a method has been invented to evaporate part of the water without the expense of fuel, by causing it to present a large surface to the air. The brine-pits, used in making bay-salt, necessarily require a large extent of level ground; but graduating houses are best adapted for mountainous situations, a place being chosen, if possible, where there is usually a strong current of air.

These graduating houses are mere carcasses of buildings, filled with thin piles of fagots, like a wall: but sometimes they are filled with a number of ropes hanging down from the rafters. The water being distributed uniformly over these piles of fagots, or ropes, by means of troughs; is exposed in a very thin surface to the action of the air, and thus evaporates quickly.

The graduating houses are covered with a roof, and are not more than ten or twelve feet thick, but often twelve or sixteen hundred feet long; the broad side being opposed to the prevailing winds. It is frequently necessary to pump up the brine twenty times or more to bring it to the required degree of strength. Cool dry winds are most favourable to the evaporation, while damp, dull, and foggy weather, sometimes even renders the brine weaker.

Fig. 112, represents a graduating house.
*A*, the transverse section of the building.
*B*, longitudinal section.
*C*, fagots of thorns, piled up in two tiers below and one above.
*D*, wooden troughs, to distribute the water over the fagots.
*E*, plan and perspective view of the troughs.
*F*, notches through which the water runs out, in slender streams, on the fagots.
*G*, roof, covered with tiles, laid so as to keep out the rain, but admit a free circulation of air between them.
*H*, cistern receiving the water.

*White salt*, as it is prepared from various saline liquors, may be distinguished into the following kinds: 1, marine boiled salt, which is extracted from sea water by boiling; 2, brine, or fountain salt, prepared by boiling from natural brine, whether of ponds or springs; 3, that prepared from sea water, or any other kind of salt water, first heightened into a strong brine, either by the heat of the sun and the operation of the air, or by evaporation, accelerated by mechanical means; 4, that prepared from a strong brine or lixivium drawn from earths, sands, or stones,

impregnated with common salt; 5, refined rock-salt, which is boiled from a solution of fossil salt in sea water, or any other kind of salt water, or pure water; 6, lastly, *salt upon salt*, which is bay-salt dissolved in sea water, or any other salt water, and then boiled into white salt; and, under these heads, may be ranked the several kinds of white salt now in use.

The salt boilers, and particularly those who prepare brine salt, have long been accustomed to make use of various substances, which they call additions or seasonings, and mix them with the brine while it is boiling, either when they first observe the salt begin to form, or else afterwards, during the time of granulation. These additions they use for various purposes. First, to make the salt grain better, or more quickly form into crystals; secondly, to make it of a small fine grain; thirdly, to make it of a large, firm, and hard grain, and less apt to imbibe the moisture of the air; fourthly, to render it more pure; and, lastly, to make it stronger, and fitter for preserving provisions.

These additions are wheat flour, resin, tallow, new ale, stale beer, bottoms or lees of ale and beer, wine lees, and alum. Wheat flour and resin are used for the property they possess of giving the salt a small grain. Butter, tallow, and other unctuous bodies, are commonly applied, as they are said to make the brine crystallize more readily; for which end, some salt boilers more particularly prefer the fat of dogs: but others have little to plead for their using these substances but immemorial custom: how far they have the effects ascribed to them, can only be determined by experiments; as several boilers, who formerly used them, now find they can make as good salt without them. Wine lees, new ale, stale ale, the lees of ale and beer, are now generally rejected by the marine salt boilers, except in the west of England, where the briners who use them affirm that they raise a large grain, and make their salt more hard and firm; and some say, that they make it crystallize more readily. Hoffman prefers the strongest ale; and Plott assures us, that it makes the salt of a larger or smaller grain, according to the degree of its staleness. The only good effects that fermented liquors can have as an addition, are probably owing to their acid spirit, which may correct the alkaline salts of the brine, and so render the common salt more dry and hard, and less apt to dissolve in moisture. If, therefore, it should be thought necessary to use any of these additions, in order to correct the alkaline quality of the brine, stale ale, or Rhenish wine, ought to be chosen, as new ale contains but little acid.

Alum is an addition long known and used in Cheshire, together with butter, to make the salt precipitate from some sorts of brine, as we are assured, by Dr. Leigh, in his Natural History of Lancashire, Cheshire, &c. who first taught the Cheshire salt-

boilers the art of refining rock-salt. As the bad properties of their salt proceeded from hard boiling, they found every method ineffectual till they had recourse to a more mild and gentle heat. And as alum has been long disused among them, it is not likely that they found any extraordinary benefit from it, otherwise they would scarcely have neglected it, and continued the use of butter. Lowndes endeavoured to revive its use, asserting, that brine salt had always two main defects, flakyness and softness; and, to remedy these imperfections, he tried alum, which fully answered every thing he proposed, for it restored the salt to its natural cubical shoot, and gave it a proper hardness; nor had it any bad effect whatever. Neither does it here seem wanted, for the grains of common salt were always sufficiently hard, and of their natural figure, large size, and no ways disposed to run by the moisture of the air, if formed by a gentle heat, and perfectly free from heterogeneous mixtures: so that the goodness of Lowndes' salt did not seem owing to the alum, with which it was mixed, but chiefly to the gentle heat used in its preparation.

The Dutch, who have long shown the greatest skill and dexterity in the art of boiling salt, make use of another addition, which they esteem the greatest secret of their art. This is whey, kept several years till it is extremely acid; which has been long held in great esteem by the Dutch, for the good effects it has on their salt, which it renders stronger, more durable, and fitter to preserve herrings and other provisions.

A decided preference having been given to foreign salt prepared in warm climates, by the spontaneous evaporation of sea water, as a preserver of animal food; and great quantities of it are imported into Great Britain; Dr. Henry, therefore, thought it of importance to determine whether this preference was well founded; and if British manufactured salt was really inferior to foreign salt, to ascertain, as the basis of all attempts towards its improvement, in what this inferiority precisely consists.

Cheshire stoved salt, or lump salt, is made from brine, by a boiling heat (226° Fahr. in fully saturated brine,) until only so much water is left as is barely sufficient to cover the small flaky crystals that have fallen to the bottom of the boiler. The salt is then put into conical wicker baskets, and after being drained, is dried in stoves where it loses about one-seventh of its weight.

Cheshire common salt is made from brine, boiled until it is brought to the point of saturation, and the evaporation finished by a heat of 160° or 170° Fahr. It is in quadrangular hoppers, close and hard in their texture; it is drained, but not stoved.

Cheshire large grained flaky salt is made from brine, evaporated at a heat of 130° or 140° Fahr. It is rather harder than common salt, and approaches to a cubical form.

Cheshire large grained or fishery salt is made from brine, evaporated at a heat of only 100° or 110° Fahr. The process lasts for seven, eight, or even ten days, and the salt forms in large and nearly cubical crystals.

Stoved salt is sufficient for domestic uses; common salt is adapted for striking and salting provisions not intended for sea voyages or warm climates; for which purposes the large grained or fishery salt is peculiarly fit.

On the first application of heat to the brine, a deposite is formed, which is either removed by skimming, or allowed to subside along with the salt first formed, and then raked out. Some brines scarcely require any of this clearing of the pan. Some part, however, sticks to the bottom, and becomes very hard, so that the pan scale (as it is called) must be removed by violence once in three or four weeks.

In Scotland, the sea water is evaporated from first to last by a boiling heat, so that the salt produced approaches to the character of stoved salt: but in some places, the fires being slackened between Saturday and Monday, the crystals are considerably increased in size, and the salt is called Sunday salt.

At Lymington, the sea water is spontaneously evaporated in shallow pits to one-sixth of its bulk before it is brought into the boilers, where the remainder of the water is entirely evaporated, and the whole mass of salt taken out at once, and removed into troughs with holes in the bottoms, through which the bittern or bitter liquor drains into pits. Under the troughs, and in a line with the holes, are fixed stakes, on which a portion of salt crystallizes. These salt cats (as they are called,) weigh about 60 or 80 pounds. When the manufacture of salt is suspended by the coldness of the weather, the bittern is evaporated; during which, some common salt is separated and reserved for the purpose of concentrating the brine in summer.

The evaporated brine is then removed into coolers, where, if the weather prove cold and clear, Epsom salt crystallizes; the quantity of which is about one-eighth of the boiled liquor, and four or five tons of it are obtained from a quantity of brine, which has yielded 100 tons of common salt, and one ton of cat salt. This single Epsom salt being again dissolved and crystallized, is called double Epsom salt. As Bergmann had erroneously excluded sulphate of magnesia from the composition of sea water, his authority has led some to suppose that either sulphuric acid or some sulphate must be added to the bittern to manufacture Epsom salt, which is not the case.

In Cheshire, the water of the river Mersey is saturated with rock-salt, so that 100 tons of the brine will yield at least 23 tons of common salt; whereas, the same quantity of sea-water,

with an equal expenditure of fuel, would produce only 2 tons 17 cwt. of salt.

Some attempts have been made to use rock-salt, crushed between iron rollers, to the packing of provisions; but the results are not perfectly known.

A large proportion of what is sold in London as bay salt, is Cheshire large grained, or fishery salt.

1000 parts of St. Ube's bay salt contain 960 of muriate of soda, 4½ of sulphate of magnesia, 23½ of sulphate of lime, 3 of muriate of magnesia, a trace of muriate of lime, and 9 of insoluble matter.

St. Martin's bay salt contains 959½ muriate of soda, 6 sulphate of magnesia, 19 sulphate of lime, 3½ muriate of magnesia, a trace of muriate of lime, and 12 of insoluble matter.

Oleron bay salt contains 964¼ muriate of soda, 4¼ sulphate of magnesia, 19½ sulphate of lime, 2 muriate of magnesia, a trace of muriate of lime, and 10 of insoluble matter.

Scotch common salt contains 935½ muriate of soda, 17½ sulphate of magnesia, 15 sulphate of lime, 28 muriate of magnesia, and 4 of insoluble matter. The quantity of muriate of magnesia was however very variable.

Scotch Sunday salt contains 971 muriate of soda, 4½ sulphate of magnesia, 12 sulphate of lime, 11½ muriate of magnesia, and 1 of insoluble matter.

Lymington common salt contains 937 muriate of soda, 35 sulphate of magnesia, 15 sulphate of lime, 11 muriate of magnesia, and 2 of insoluble matter. Here also the quantity of muriate of magnesia is variable.

Lymington cat salt contains 988 muriate of soda, 5 sulphate of magnesia, 1 sulphate of lime, 5 muriate of magnesia, and 1 of insoluble matter.

Cheshire crushed rock-salt contains 983¼ muriate of soda, 6½ sulphate of lime, 3-16ths muriate of magnesia, 1-16th muriate of lime, and 10 of insoluble matter.

Cheshire fishery salt contains 986¾ muriate of soda, 11¼ sulphate of lime, ¾ muriate of magnesia, ¼ muriate of lime, and 1 of insoluble matter.

Cheshire common salt contains 983½ muriate of soda, 14½ sulphate of lime, ¾ muriate of magnesia, ¼ muriate of lime, and 1 of insoluble matter.

Cheshire stoved salt contains 982½ muriate of soda, 15½ sulphate of lime, ¾ muriate of magnesia, ¼ muriate of lime, and 1 of insoluble matter.

The insoluble matter in foreign salt is chiefly argillaceous earth coloured by oxide of iron; in sea salt prepared by rapid evaporation, it is a mixture of carbonate of lime with carbonate of magnesia, and a fine silicious sand; in that from Che-

shire brine it is almost entirely carbonate of lime; in the less pure species of rock salt it is chiefly a marly earth with some sulphate of lime, and its quantity varies from 10 to 45 parts in a thousand; hence government allows 65 pounds for the legal weight of a bushel of rock salt, instead of 56 pounds, as in bay and white salt.

The earthy muriates seem to be derived from the mother liquor that adheres to the salt. They scarcely form one-thousandth part of the Cheshire varieties of salt; and indeed if the brine be evaporated to dryness, it does not contain more than 5 parts in 1000 of earthy muriates, whereas the entire salt of sea water contains 213.

That sulphate of lime is found in a larger proportion in bay salt than even in those that are prepared by the rapid evaporation of sea water, seems owing to its being either separated from the latter brines in the clearing of the boiler, a process which cannot be performed in the clay-pits, or to its entering into the composition of the pan scale. The proportion of it is very variable, depending upon the period in which the salt was extracted from the boiler; for common salt taken out two hours after the first application of heat, contained 16 parts in a thousand of sulphate of lime; four hours, 11 parts; and six hours, only 3½ parts. On the other hand, the contamination of salt with the earthy muriates increases as the process advances.

The several varieties of salt appear to contain nearly the same quantity of water after they have been dried by a heat of 212° Fahrenheit. Pure transparent rock-salt did not lose any of its weight in a low red heat, nor did it decrepitate, like the artificial varieties, when suddenly and strongly heated. The salts that contain muriate of magnesia are decomposed and deprived of their acid, by a low red heat. 100 parts of dry large grained fishery salt loses about three parts of water, St. Martin's bay salt, the same; Oleron bay salt 2½; Cheshire common salt, 1½; Cheshire stoved salt ½. The loudness of the decrepitation was in the same order, and was most remarkable in the large grained varieties.

The proportion of the other ingredients in the muriate of soda contained in these salts appeared to be nearly the same in all, and the difference existing between them for economical purposes, do not depend upon any difference in their chemical composition, but on the magnitude of their crystals, and their degree of compactness and hardness. Quickness of solution is, in similar circumstances, proportional to the quantity of surface exposed, and therefore since the surfaces of cubes are as the squares of their sides, a salt whose cubic crystals are of a given magnitude, will dissolve four times more slowly than one whose cubes have only half that size: of course the large

salt will, when used for packing provisions, remain permanently between the layers, or will be very gradually dissolved by the exuding fluid; on the other hand, the smaller grained salts answer equally well, if not better, for the purpose of preparing the pickle, or striking the meat.

Little or no difference in specific gravity is discoverable between the large grained salt of British, and that of foreign manufacture; and even if no superiority be claimed on account of the greater chemical purity of British salt, it may safely be asserted that the larger grained varieties are fully equal to foreign bay salt, as to their mechanical properties, and that the prejudice in favour of the latter may be discarded as imaginary.

### *Tincal, or Rough Borax.*

Tincal, or rough borax, is imported from the East Indies, where it is said to be obtained by evaporating the water of certain lakes, either in shallow basins, as in making bay salt, or by fire: the tincal thus obtained, is then moistened with sour milk, in order to prevent the crystals from falling to powder.

1000 parts of tincal were found, by Klaproth, to contain 145 of soda, 370 of boracic acid, and 470 of water: that is to say, $Na.B^{8} + 24\,(H{\cdot}H_{2})$ according to Berzelius' notation.

Tincal is used for manufacturing refined borax.

### *Refined Borax.*

The refining of tincal into borax was formerly considered as a great secret; and its manufacture was confined to Holland: as the numerous attempts of the chemists of other nations were unsuccessful, apparently from their ignorance that an addition of soda was requisite to saturate the surplus boracic acid in tincal.

Refined borax may be obtained by calcining tincal, boiling it with the necessary quantity of carbonate of soda, filtering the solution, and letting it cool: the small crystals thus obtained, are to be again dissolved in water, and crystallized as before, only letting the solution cool very gradually, as in crystallizing sugar.

Another method is, to put the tincal upon a cloth stretched over a colander, so as to form a layer of not more than a foot thick; it is then washed with a small quantity of pure soda water at 5 degrees Baumé, until the soda water passes but slightly coloured. The washed tincal is thrown gradually into a leaden boiler of water, until the water acquires the strength of 20 degrees Baumé; twelve pounds of carbonate of soda are then added for every 100 of washed tincal in the water; the ley is then left to settle and crystallize.

The mother waters being very highly coloured, are evaporated to dryness, then calcined, again dissolved, and the solution crystallized as before.

But at present, the French have ceased to import tincal, and manufacture all their borax, of which they annually consume about twenty-five tons, from the boracic acid obtained from the Italian lakes.

For this purpose, the manufacturer dissolves, gradually, 1200 pounds of carbonate of soda in 1000 pounds of water, and adds, by twenty pounds at a time, 600 pounds of Tuscan boracic acid. As the effervescence is considerable, the leaden boiler must hold double the quantity, and a fresh parcel of acid must not be added until the surface of the water is cleared.

The whole of the acid being added, the fire is stifled by a covering of ashes placed over the coals; the damper in the chimney is shut to prevent any draught; the boiler is covered with a double lid made of sheet lead, and blankets thrown over that to keep in the heat. At the end of thirty hours the cleared liquor is drawn off into leaden coolers, where its depth should not exceed a foot, where the first crop of crystals will be formed in three or four days.

As the market requires the crystals to be of considerable size, the first crop is struck off the coolers by a chisel and mallet, and re-dissolved in boiling water, adding one-tenth of their weight of carbonate of soda, until the ley is at 20 degrees Baumé; and, to attain the proper marketable size, as Dutch refined borax, not less than a ton of borax should be crystallized at once. The solution being finished, it is drawn off into a large square wooden cistern, about six feet each way, lined with very thick sheet lead, several of which ought to be prepared, and fixed in another case at such distance as to allow the cistern, containing the liquor, to be surrounded on all sides, and also covered at top with woollen mattresses to keep in the heat. Here the solution must remain at perfect rest for seventeen or eighteen days before it cools to 86 degrees Fahrenheit. When the cistern is opened, the mother water is drawn off by a syphon, and the cistern shut up again for six or eight hours to cool slowly, that the crystals may not crack.

At the last, the crystals are adroitly cut out of the cistern with a sharp chisel, in large masses, and afterwards broken into separate crystals; those that are less weight than two avoirdupois drams are flung aside, and if the larger crystals have any spots of borate of lime, or borate of magnesia attached to them, these spots are struck off by a sugar hatchet.

The small crystals are added to the next batch; and the mother water of the first crop of crystals is used to dissolve the carbonate of soda for the succeeding batches.

One hundred pounds of the best Tuscan boracic acid, containing about half its weight of the pure acid, produces in experiments about 150 of refined borax; but, as the ordinary acid

contains only about 48 pounds of pure acid, and there is a considerable loss in the repeated solutions necessary to obtain full-sized marketable crystals, the manufacturer cannot expect more than 140 or 142 pounds of borax from 100 of boracic acid.

The manufactories must be placed where the crystallizing cisterns are not exposed to the vibration occasioned by carriages passing along paved streets; and these must be so solidly fixed, that the knocking of the crystals from one cistern may not communicate any motion to the others, as this would prevent the crystals from obtaining their full size.

In consequence of this improvement, the price of refined borax has fallen in France from about five shillings and ten-pence the pound to two shillings and two-pence; and it might be sold lower if the consumption was increased.

Borax is used in soldering; in forming artificial gems; in melting the precious metals; and in glazing china-ware.

Refined borax, the *bi-borate of soda* of Thomson, contains 2 B: $Na \cdot + 8 H \cdot$, equal to 19,000; but Berzelius makes his *boras natricus* $N: B_2 + 10 (H \cdot H)$ or 2,453,820.

### *Rochelle Salt.*

This purgative salt, used by the higher classes in society, is the *tartarate of potassa and soda;* or, rather, the *potassa tartarate of soda* of the chemists, and the *soda tartarizata* of the medical faculty.

It is formed by dissolving twenty ounces of carbonate of soda in ten wine pints of water, and adding, gradually, twenty ounces of cream of tartar, filtering the solution, evaporating it to a skin, and crystallization.

According to Berzelius, his *tartras kalico natricus cum aqua* is probably $K: T^{-2} + N: T^{-2} + 20 (H \cdot H)$ equal to 7,548,390: Thomson makes it $K \cdot T_2 + N \cdot T - 8 H \cdot$, or 35,500; and Phillips agrees with Thomson, as to the composition of the salt, but says it contains no water of crystallization; so that he makes it 214, supposing hydrogen to be the unity, or 26,750 on Thomson's scale.

### *Phosphate of Soda.*

This was originally known by the name of *sal mirabile perlatum;* but was introduced into more general notice by that of *tasteless purging salt.* It is used in chemistry to discover magnesia in mineral waters and acid solutions.

It is made by dissolving 1400 grains of crystallized carbonate of soda in 2100 of water, at 150 degrees Fahrenheit; to this is to be added, gradually, 500 grains of phosphoric acid, specific gravity 1·85, boiling the mixture for a few minutes, filtering it, and letting it crystallize by cooling; from 1450 to 1550 grains of phosphate of soda crystallizes.

Or, forty wine pints of boiling water are poured on twenty pounds of bone ash, and sixteen pounds and a half of oil of vitriol, previously diluted with an equal weight of water, added; the next day the liquor is strained off, and the sediment washed,

to get out all the acid; the whole of the mixed liquors is evaporated to half its quantity, left to settle, and then strained, evaporated again to dryness, melted in a crucible, and dissolved in water. Carbonate of soda is added to the impure phosphoric acid thus obtained, to throw down the remains of the lime, and the liquor is then filtered and crystallized.

### *Microcosmic Salt.*

This salt, which is much used in assaying minerals by the blow-pipe, was originally extracted from urine, and hence derived its name of *fusible salt of urine;* it is also called *salt of phosphorus*, as in Berzelius' Treatise on the Blow-pipe; but the theorists denominate it *phosphate of ammonia and soda*, or *ammonia phosphate of soda.*

Berzelius makes it by dissolving sixteen parts of sal ammoniac in a very small quantity of boiling water, adding 100 parts of crystallized phosphate of soda, filtering the solution, and letting it cool slowly, when small crystals are formed. The mother water contains common salt and an acidulous phosphate, which will require to be saturated with ammonia, if it be desired to make use of this water. If the microcosmic salt is not pure, it melts into an opake globule, and must be re-dissolved and re-crystallized.

### *Succinate of Soda Water.*

This is only used as a means for discovering iron in mineral waters and acid solutions, and separating that metal from them.

It is prepared by adding succinic acid to carbonate of soda water, so that the liquor may contain a slight excess of acid beyond what is necessary for the saturation of the soda.

## VOLATILE ALKALI, OR AMMONIA.

This alkali has escaped very well in the mania for changing names, although some theorists are for giving it a name that may denote its supposed composition from azote or nitrogen gas, and hydrogen gas; since, according to the theory of the common schools, it is formed from three measures of hydrogen gas, united with one of azote or nitrogen gas, condensed into two measures, or half the bulk of its constituent elements; and hence its atomic weight, according to Thomson, is 2,125. Berzelius, on the other hand, makes it $N \cdot H^6$, and its weight 214,570; so that, according to this theory, 100 parts of it contain 46 parts ·6 of oxygen: and, indeed, its power of saturating acids is equivalent to that of other alkaline bases containing that proportion of oxygen.

*Pure ammonia, ammoniacal gas*, or, as it was originally called by its discoverer, Dr. Priestley, *alkaline air*, is obtainable from ammonia water by a gentle heat. It must be collected in jars standing in a trough of quicksilver, as it is rapidly absorbed by water, one measure of which takes up 780 measures of the gas. It is of no use.

### *Ammonia Water.*

This was originally called *spirit of sal ammoniac made with lime*, then *volatile alkaline spirit of sal ammoniac*. It is the *liquor ammoniæ* of the present medical faculty; and the *liquid ammonia* of many chemists, though this name now denotes the condensed gas.

It may be prepared, in a small way, by slaking six ounces of quicklime with a pint of water, and, in an hour's time, adding a boiling hot solution of eight ounces of sal ammoniac in three pints of water, covering the vessel, straining the liquor when cold, and distilling off twelve ounce-measures into a receiver, kept in a tub of water at 50° Fahr.

Mr. Woulfe made the following experiment on the distillation of sal ammoniac with quicklime. Twelve pounds of British sal ammoniac, and twenty-six pounds of quicklime, were powdered, mixed, and put into an iron body, with a stone-ware head, to which his first apparatus was fitted; and, when the apparatus was luted, a gallon of water was poured on it through the pipe in the top of the head, which was immediately stopped. The lime growing hot produced a vast quantity of elastic air, which, though highly charged with volatile alkali, was condensed by the water, only the air escaping at the top of the vessel, with hardly any sensible volatile alkaline smell. Next morning, all being cold, another gallon of water was added as before, and a very slow fire made under the body for fourteen hours, in which time there distilled nearly a pound of volatile alkali; the fire was then made stronger, and continued in that state for twelve hours more; in which time there was obtained, together with what was first distilled, eight pounds and a quarter of volatile alkali, strong, and fit for eau de luce; this was taken out of the bottle and set apart. The vessels being cool, two gallons more of water were put into the body, and the fire made as before, and continued till there were seven pounds distilled of weak volatile spirit: this spirit answers better than water in case of a fresh distillation.

During the first sixteen hours of the distillation, there continually escaped through the water in the bottle air very slightly charged with volatile alkali, especially when the water got hot; but afterwards no air was set free.

Two stone gallon bottles, with three quarts of water in each, were made use of to condense the vapours; and when one bottle was got warm by the fumes, the other was put in its place, while it was cooling in a vessel of cold water, and so continually changed during the whole operation. The six quarts of water increased by this means two pounds and a half in weight; and, by the following experiments, it appears that a pound of this vapour condensed in the water, is to a pound of the volatile alkali, which was set apart for eau de luce, as 140 to 76, which is nearly

twice as much; therefore there was a saving of nearly five pounds of volatile alkali, which would have been lost in the common manner of distillation.

The water of the two stone bottles, charged with alkaline vapours, was mixed, in order to reduce them to the same degree of strength, and as much of it was put into a glass body as contained four ounces of the alkaline vapour; four ounces of the volatile alkali, which was set apart for eau de luce, was put into another body of the same size, and diluted with water to the same bulk of the other.

This last took one pound three ounces of oil of vitriol, diluted with water, to be saturated, and did not become hot; whereas, the water, containing the four ounces of the alkaline vapour, absorbed by water, required two pounds three ounces of the same acid, and got so very hot, that the vessel could scarcely be held in the hand, even after having been diluted, at different times, with two quarts of water. This shows that there is a great difference in the two, and that it is not entirely owing to strength. The heat produced by the vapours passing through the water was tried at another distillation, and the heat was raised to 110 degrees Fahrenheit.

In rectifying caustic volatile alkali with lime, there is likewise a very great quantity of air set free, highly charged with volatile alkali, which condenses in water and heats it. Water may be so strongly charged with this vapour, that it will make very strong eau de luce, nay, much stronger than that which was distilled and set apart for eau de luce; but it is necessary to make use of two stone bottles, changing them as often as they get warm.

The specific gravity of ammonia water, for medical purposes, is ordered to be 0·960, and contains about one-tenth its weight of ammoniacal gas; but Dr. Henry advises that used for the examination of mineral waters and acid solutions to be kept at 0·970, in order that a measure of it may saturate an equal measure of sulphuric acid at 1·135, of nitric acid at 1·143, of muriatic acid at 1·074. The strongest ammonia water that can be kept, without extraordinary care, is at 0·954, which contains very nearly one-third its weight of ammoniacal gas, or 15 atoms of water to one of ammonia.

### *Sulphate of Ammonia.*

This is now made from the ammoniacal liquor obtained as a secondary product in the distillation of coal for gas. A chaldron of Newcastle coal yields, in general, about 200 pounds of ammoniacal liquor, which chiefly consists of sulphate of ammonia and carbonate of ammonia. A gallon, or eight pounds and a half of that obtained from strong burning coal, usually requires for its saturation from fifteen to sixteen ounces of oil of vitriol, of the specific gravity 1·840; but the same quantity of liquor from coals burning to a white ash, do not require more than nine ounces.

The strength of the liquor must be first ascertained, by putting several half pints of it into different vessels, and adding to each a different number of avoirdupois drams of calcined gyp-

sum, reduced to fine powder: the mixture is well stirred and left for three or four hours. Pieces of paper, tinged blue with archil, are then dipped in each vessel, and that vessel is noted in which the archil paper is turned red with the smallest quantity of calcined gypsum.

The ammoniacal liquor being measured, or gauged, to every eight gallons there is to be added calcined gypsum, in the proportion of a pound for every dram that the assayed half pint required. The mixture is stirred together, and when it has settled, the liquor is drawn off and evaporated; at first a portion of sulphate of lime falls down, and must be removed; the sulphate of ammonia then begins to show its crystals, which are drawn out of the boiling liquor, and drained in baskets placed round the boiler, so that the liquor that drains off may run into the boiler again, and this is continued until the whole is evaporated to dryness.

Eighty-four pounds of sulphate of ammonia are, upon an average, produced from 54 gallons of the ammoniacal liquor from Newcastle coals, and 63 pounds of calcined gypsum.

Sometimes the ammoniacal liquor is saturated with oil of vitriol; but in this case, the sulphate of ammonia is contaminated with oil, which must be got rid of, by heating it gently, with constant stirring that every part may be heated alike, until one part of the oil being steamed away, and the other reduced to a coal, the solution in water is colourless.

Sulphate of ammonia is used for the manufacture of sal ammoniac and volatile salt. It contains one atom each, acid, alkali, and water; but that analysed by Berzelius contained two of water.

### *Nitrate of Ammonia.*

This has been called *nitrum flammans*, from its sudden expansion by heat. It has but lately come into use for the production of nitrous oxide gas, or intoxicating gas.

It is made by saturating dilute nitric acid with sesqui carbonate of ammonia, evaporating the liquid, if necessary, and letting it crystallize.

This salt consists of one atom each of ammonia and of nitric acid; and according to Sir H. Davy, it varies in its proportion of water, assuming a correspondent variety of form.

### *Sal Ammoniac.*

The name bore by this salt for nearly 2000 years, has been lately changed by the southern chemists into that of *muriate of ammonia*, and by the northern chemists into *murias ammonicus*.

It has been in common use for several centuries, and was formerly brought from Egypt. Nothing was for a long time known of the constituents of the salt, or of the mode of preparing it. In the year 1719, the French consul at Grand Cairo, M. Lemeri, sent an account of the mode of manufacturing it in Egypt. The

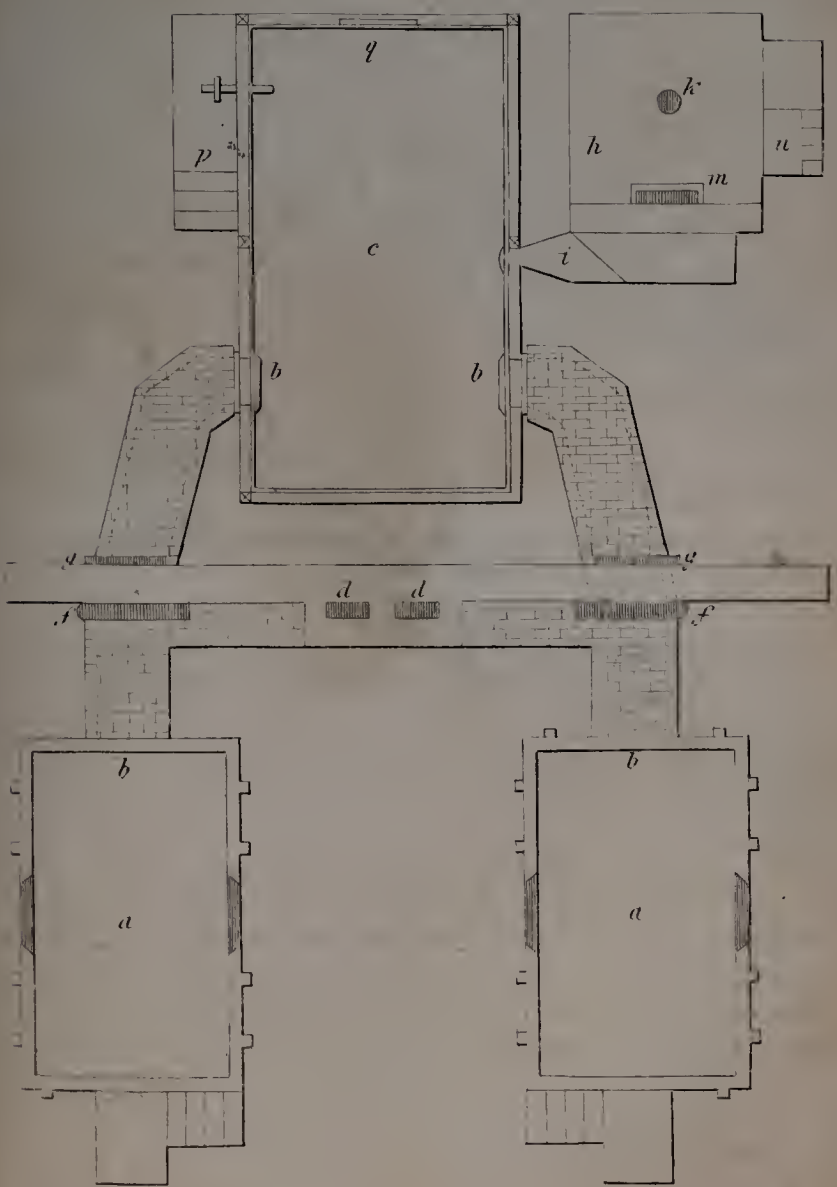
natives collect the excrements of camels, oxen, and other animals, which feed on saline plants. This is dried and used as fuel, the soot is collected and put into large glass bottles, 18 or 19 inches in diameter, terminating in a neck several inches high. The bottles are filled within four fingers' breadth of the top, and then heated for three days. Towards the second day sal ammoniac sublimes and adheres to the upper part of the bottle. When the process is finished, and the vessels cooled, they are broken, and the sal ammoniac taken out for sale. About one pound of sal ammoniac is obtained from five pounds of soot.

After the discovery of its constituent parts, establishments for manufacturing it were soon set on foot in various parts of Europe. The first were in England and Scotland; it was known that carbonate of ammonia is disengaged from several animal substances in the process of putrefaction, and could be obtained in great abundance by subjecting the horns, bones, and hoofs of animals, or fish, to distillation; the most obvious method of effecting the combination, was a direct mixture of the acid and alkali, but owing to the waste of the gaseous alkali, this mode was soon found not to be economical.

Fig. 113, represents the ground plan of an apparatus employed by M. Leblanc, at St. Denis, near Paris, for manufacturing sal ammoniac, by decomposing common salt by sulphuric acid, in a kind of reverberatory furnace, the floor of which is covered with lead, and the vapour of muriatic acid being conveyed into an adjoining leaden chamber, it is there at the same instant met by the vapour of carbonate of ammonia, produced from animal matters, which are distilled in three iron cylindrical retorts placed in a furnace. The decomposition of the common salt is not, however, entirely effected in a first furnace, so that it is removed into a second, capable of giving a great heat. The alkaline residuum of the salt is employed to furnish crystallized soda.

*A*, are two furnaces for decomposing common salt, each 14 feet long, by seven feet six inches wide. *B*, are brick gutters, each two feet wide, which go through the wall dividing the workshop, and conduct the vapours of muriatic acid gas into the chamber, *c*, which is made of lead, and here the muriatic acid meets the ammoniacal gas for the production of sal ammoniac. *D*, are flues belonging to the two furnaces, *a*, for carrying off the smoke of the fire places. These are 14 inches by 24 inches each, and are carried up together, and at last united into one chimney above the top of the building. *E*, are pipes belonging to the two furnaces, *a*, each 14 inches wide, connected with the chimneys, and designed for carrying off the muriatic acid gas by that conveyance into the atmosphere, when the furnaces are used for the production of soda without making sal ammoniac. *F*, are cast iron plates, or dampers, which open or shut the communication of the pipes, *e*, with the chimney, at pleasure. *G*, are similar iron dampers, which cut off the passage of the muriatic acid gas into the leaden chamber. *H*, is a ground plan of the kiln for burning the animal matters designed to produce ammonia. *I*, a leaden pipe to convey the ammoniacal gas into the chamber, *c*. *K*, is a hole through the arch, or superior part of the kiln, which is designed to receive a retort, from whence the steam of hot water is forced into the chamber, *c*, at the same moment when the acid and alkaline gasses are entering the same receptacle. *M*, the kiln chimney. *N*, is a flight of steps leading to the ash room. *O*, a pipe by which the chamber is emptied of the liquid muriate of ammonia, when necessary. *P*, a flight of steps leading under the chamber, *c*. *Q*, a door to enter the said chamber. The peculiar advantage of this apparatus is, that while the muriatic acid gas is passing into the chamber, *c*, at that moment another stream of ammoniacal gas is enter-

*Fig. 113.*



ing the same chamber from the kiln, *h*, which occasions a mutual condensation, and prevents any loss.

This salt is also manufactured from carbonate of ammonia, acted upon by sulphate of lime. Rough bone spirit is digested on ground plaster of Paris, which, in consequence of a double decomposition, is changed into carbonate of lime, and the liquor contains sulphate of ammonia.

Common salt is then added in the requisite proportions to the solution of sulphate of ammonia in water, and the liquor is evaporated; the Glauber's salt formed crystallizes, and is separated, until the muriate of ammonia begins to show itself in feathered stars, and then the liquid is run off into coolers, where the sal ammoniac crystallizes. When the liquid is cooled to 76° Fahr. the mother water must be again drawn off for a fresh evaporation, as below that temperature Glauber's salt would be deposited, and mix with the sal ammoniac.

The moist sal ammoniac is drained, and then sublimed in earthen jars, or glass bolt-heads.

The use of coal gas lights having introduced a quantity of ammoniacal liquor into the market, the sulphate of ammonia made from it has been used for the manufacture of sal ammoniac.

Sal ammoniac is used by dyers to modify the shades of various colours, and it is added in considerable quantity to snuff, to make it pungent. A large quantity is used by the workers in metals, particularly in soldering; it is said that twenty tons are used yearly in Birmingham, by these artificers.

Sal ammoniac, newly sublimed, or well dryed, consists, according to Berzelius, of $N \cdot H^6 M$:, equal to 558,090, but according to Thomson, of $Cl\,H + Az\,H^3$, equal to 6,750.

## *Hartshorne, or Bone Spirit.*

This is also called *crude ammonia*, and the manufactory of it is carried on upon a large scale in several parts of the kingdom. The materials distilled are in general bones and hoofs of animals: though the refuse of slaughter-houses, and urine, is used for the same purpose.

In this distillation an iron still or retort is generally used, with a pipe leading from it, connected with a worm-tub. The vessel being filled with bones roughly broken, or other material, a strong heat is applied. Water, and a tar-like oil, first comes over, accompanied by a very fetid inflammable gas. Carbonic acid gas also comes over, but the latter is mostly taken up by the ammonia, which is also formed at the same time, and they come over into the receiver in the state of carbonate of ammonia. When the different substances have been condensed in the worm, they should pass into a receiver, which has no communication with the open air, as this would

not only render it almost impossible to exist in the same place, but would constitute a nuisance in the vicinity of any town.

The receiver should have no opening outwards, but through a pipe inserted into the upper part of it, and connected with the ash room of the still. The inflammable gas and the smell are conveyed to the fire, where the former takes fire and burns; but care must be taken to avoid any explosion, for when the evolution of the inflammable gas becomes slow, or ceases entirely, the common air passes along the pipe into the close receiver, which is filled with the same inflammable gas; and under these circumstances an explosion will take place, which will not only burst the receiver, but do other injury. This evil may be avoided by placing a valve in the pipe, opening outwards, to allow the passage of the gas, and another valve in the receiver, opening inwards, by this means the flaming gas will be stopped in its passage to the receiver; as the valve into the receiver opening will admit the common air to fill up the vacuum. And thus by means of this apparatus, if it be well constructed, and proper luting employed, the distillation of hartshorn may be carried on almost without any smell, although the odour of animal oil is so remarkably offensive.

The first product consists of water, animal tar, and volatile salt. A great part of the tarry oil may be separated mechanically; the rest, in great measure, by a second distillation with a gentle heat. The liquid which comes over consists of a solution of sesqui carbonate of ammonia, with a fetid animal oil, which gives it a peculiar odour. This liquid has been sold in the shops under the name of *spirit of hartshorn*, as the alkaline liquor obtained from that substance, was at one time thought to possess certain medical virtues, not to be found in the alkaline liquor obtained from other animal matters.

Hartshorn, or bone spirit, is used for preparing sulphate of ammonia, and for purposes in which the smell of the oil is not of any consequence.

### *Volatile Salt.*

The original name of this salt, was *volatile salt of sal ammoniac*, or the *volatile salt* of the substances from which it was procured, being mostly hart's horn, vipers, or urine. In the French nomenclature it was *carbonate of ammonia;* this has been changed by some into *sub-carbonate of ammonia*, but lately it has been called the *sesqui carbonate of ammonia*, as the freshest specimens always contain a charge and a half of carbonic acid, to one of ammonia, and its alkali gradually flies off from the exterior surface, which is thus converted into the bi-carbonate of ammonia, the interior generally remaining unchanged.

It is obtained in the distillation of most animal substances, and of some few vegetables; but when prepared in this manner it is contaminated with an oil, which, except in the case of being obtained from the cast horns of deer is very unpleasant.

Volatile salt is sometimes made, by subliming a mixture of eight ounces of sal ammoniac, with ten ounces of chalk, both previously well dried.

At present it is mostly prepared from purified sulphate of ammonia, which is mixed with one quarter of its weight of chalk, finely ground and previously deprived of its moisture by heat. As soon as possible after the mixture is made, it is introduced into cast-iron retorts, at a dull red heat, but as soon as the lids are made air-tight, the fire is raised gradually, till the retort becomes a bright cherry red. The carbonate of ammonia is conveyed by a four-inch pipe, which proceeds from the upper extremity of each retort, opposite to the mouth-piece, into a barrel-shaped leaden, or cast-iron receiver, where it condenses. The receiver is furnished with a leaden cover, secured by a water joint; it is provided also at its bottom with a small pipe, furnished with a stopper, and till the liquid products are got rid of during the process of sublimation, this pipe is left open. To give vent to the elastic fluid, evolved during the process, a small hole is made in some convenient part of the cover, which is slightly stopped by a wooden peg. The receiver should be supported upon a stand, so as to raise it a foot or eighteen inches from the ground.

The time which is necessary for completing the operation, varies according to circumstances, but the sublimation of a charge of 120 pounds of the mixture in one retort, is usually finished in twenty-four hours.

Dry sulphate of ammonia produces about half its weight of sesqui carbonate of ammonia.

Volatile salt is used as a stimulating odorous substance, either pure in smelling bottles, or mixed with snuff. It is also used in large quantities by the bakers, to raise their bread lighter and quicker than by yeast alone.

### *Bi-Carbonate of Ammonia Water,*

Is prepared by merely exposing sesqui carbonate of ammonia in small grains to the air, until it has lost its pungent smell, and then dissolving it in water.

It is used to ascertain the presence of magnesia in mineral waters, or acid solutions.

### *Oxalate of Ammonia Water,*

Is prepared by saturating liquid oxalic acid with volatile salt.

It is used to ascertain the presence of lime in mineral waters.

### *Benzoate of Ammonia Water,*

Is prepared by saturating liquid benzoic acid with volatile salt.

It is used to ascertain the presence of iron in mineral waters, and acid solutions.

## LIME.

Lime is considered as the oxide of a metal called calcium. Berzelius makes it Ca:, and its weight 712,060; and Dr. Thomson only C·, or 3,500. It is generally considered as an earth, but is soluble in 700 times its weight of water, and the water has an acrid taste, and turns syrup of violets green.

### *Quicklime.*

Quicklime is obtained from limestones, chalk, or shells, by burning them in kilns.

Lime kilns are built of different forms or shapes, according to the manner in which they are to be wrought, and the kinds of fuel which are to be employed.

The best form of a lime kiln, in the practice of the present day, is that of the egg placed upon its narrower end, having part of its broader end struck off, and its sides somewhat compressed, especially towards the lower extremity: the ground-plat, or bottom of the kiln, being nearly an oval, with an eye or draft-hole towards each end of it. It is supposed that two advantages are gained by this form over that of the cone. By the upper part of the kiln being contracted, the heat does not fly off so freely as it does in that of a spreading cone: on the contrary, it thereby receives a degree of reverberation which adds to its intensity. But the other, and still more valuable effect, is this: when the cooled lime is drawn out at the bottom of the furnace, the ignited mass, in the upper parts of it, settles down, freely and evenly, into the central parts of the kiln.

It is a common practice, in some places, to burn limestone with furze or fagots. The kilns which are made use of in these cases are commonly known by the denomination of flame-kilns, and are built of brick; the walls from four to five feet thick, when they are not supported by a bank or mound of earth. The inside is nearly square, being twelve feet by thirteen, and eleven or twelve feet high. In the front wall there are three arches, each about one foot ten inches wide, by three feet nine inches in height. When the kiln is to be filled, three arches are to be formed of the largest pieces of lime-stone, the whole breadth of the kiln, and opposite to the arches in the front wall. When these arches are formed, the lime-stone is thrown promiscuously into the kiln to the height of seven or eight feet, over which are frequently laid fifteen or twenty thousand bricks, which are burned at the same time with the lime-stone. As soon as the filling of the kiln is completed, the three arches in the front wall are filled up with bricks almost

to the top, room being left in each sufficient only for putting in the furze, which is done in small quantities, the object being to keep a constant and regular flame. In the space of thirty-six or forty hours, the whole lime-stone, about one hundred and twenty, or one hundred and thirty quarters, together with the fifteen or twenty thousand bricks, are thoroughly burnt.

Mr. Dodson is convinced, from experience, that lime-stone can be burnt to better purpose, and at less expense, with peat than with coal. When coal is used, the lime-stones are apt, from excessive heat, to run into a solid lump, which never happens with peat, as it keeps them in an open state, and admits the air freely. The process of burning, also, goes on more slowly with coal. No lime can be drawn for two or three days; whereas, with peat, it may be drawn within twelve hours after fire is put to the kiln; and, on every succeeding day, nearly double the quantity of what could be produced by the use of coal. The expense is comparatively small. No particular form of kiln was found necessary, nor any particular sort of management in the process of calcination.

Mr. Rawson asserts that he has produced a considerable saving in the burning of lime, by closing his kiln at top, and building a chimney over it. His kiln is twenty feet in height, at the bottom a metal plate is placed, one foot in height, intended to give air to the fire. Over this plate the shovel that draws the lime runs. The sloped sides are six feet in height, the breadth at the top of the slope is eight feet, the sides are carried up perpendicular fourteen feet, so as that every part of the inside, for fourteen feet, to the mouth, is exactly of the same dimensions. On the mouth of the kiln a cap is placed, built of long stones, and expeditiously contracted, about seven or eight feet high. In the building of the cap, in one side of the slope, the mason is over the centre of the kiln, so that any thing dropping down will fall perpendicularly to the eye beneath. He is here to place an iron door of eighteen inches square, and the remainder of the building of the cap is to be carried up, until the hole at the top be contracted to fourteen inches. The kiln is to be fed through the iron door, and, when filled, the door close shut. The outside wall must be three feet at the bottom to batten up to two feet at top, and made at such a distance, from the inside wall of the kiln, that two feet of yellow clay may be well packed in between the walls, as every kiln, built without this precaution, will certainly split, and the strength of the fire be thereby exhausted. At eight feet high from the eye of the kiln, two flues should be carried through the front wall, through the packed clay, and to the opposite side of the kiln, to give power to the fire.

As many situations will not admit of building a kiln twenty

feet high, while other situations may allow of its being thirty, or even forty feet (for it cannot be made too high,) the diameter of the kiln should be proportioned to the height to which it is carried up.

Fig. 114, represents an elevation of the usual form in which kilns to burn lime with coal are frequently built. *A*, is the front wall of the kiln; *b*, part of a slope made to enable the workmen to mount up to the top of the kiln, to charge it with coal and lime-stone, in alternate beds. *C*, one of the three arches that lead to the fire-room, and through which the lime is withdrawn.

Fig. 115, represents the section of the kiln. *A*, the solid mass of the kiln; *b*, linings of brick or stone; *c*, the hollow cavity of the fire-room and chamber; *d*, mouth of the fire-room and ash-room; *e*, two of the three arches that lead to the fire-room entrance.

Fig. 116, represents the plan of the kiln. *E*, the three arches leading to the fire-room; *o*, iron bars placed across the bottom of the fire-room, to serve as a grate and supporter of the lime-stone.

Fig. 117, represents a section of a kiln for burning lime, by means of furze or wood. *A*, the main mass of the kiln; *b*, the brick lining of the cavity where the fire and lime-stone are placed; *c*, the chamber fitted with lime-stone; *d*, the fire-room; *e*, a workman, who is putting a fagot to the mouth of the fire-room, and holds it there until it is perfectly alight, when he drops it into the fire-room, and immediately stops up the fire-room door with another fagot, and so keeps on: *f*, the ash-room, which is an arched vault that crosses the bottom of the kiln; it has a hole in its middle which corresponds with the fire-room, and lets the small coal pass into the ash-vault.

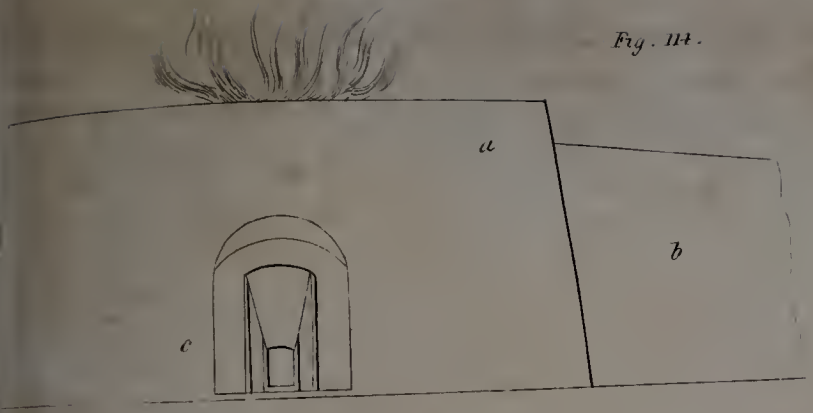
In Cambridgeshire, and many of the southern counties of England, lime is prepared from the calcination of chalk, or, as it is generally called at Cambridge, clunch. The kilns are inverted cones sunk in the earth, and lined with brick; the base of the cone is about ten feet in diameter, and the depth of the kiln is about fourteen feet. One of these kilns will burn about 150 bushels of lime in twenty-four hours; they use generally one bushel of coal for every four bushels of lime, and in summer, when the chalk is dry, they will sometimes get five bushels of lime from the consumption of one bushel of coals; but being dear, the chalk is seldom well burned.

In some parts of Yorkshire they burn pieces of calcareous slate, a foot in thickness, and a foot and half in length, without breaking them; they use generally eight dozen of coal to a kiln, and obtain 22 dozen of lime, the dozen containing 36 bushels.

On a medium of twelve experiments, 11 Cwt. 1 quarter, 4 pounds two-thirds of lime were obtained from a ton of calcareous stones, but the manufacturers do not calcine the stone so far; yet, notwithstanding the loss of weight, there is no decrease in bulk.

All kinds of lime exposed to the air, recover nearly their original weight, except chalk lime, which, although long exposed, never recovers more than seven-eighths of its original weight.

Fig. 114.



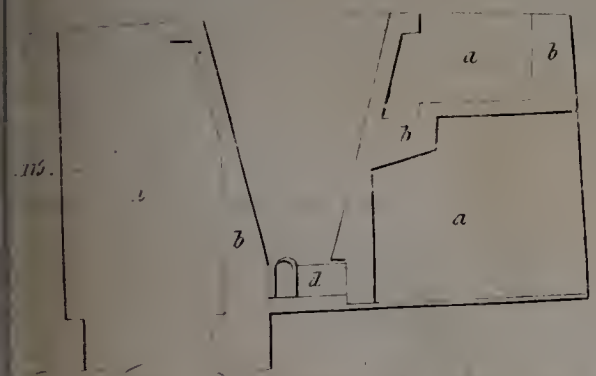



Fig 116

Fig. 117.

the quantity of spirit of wine, or of the mixture of urine and litmus, or archil, dissolved in common ley of wood ashes. An extract of saffron, and sap green, succeed well dissolved in urine and quicklime, and tolerably well in spirit of wine. Vermilion, and a fine powder of cochineal, succeed also very well in the same liquors. Dragon's blood succeeds very well in spirit of wine, as also does a tincture of logwood in the same spirit. Alkanet root gives a fine colour, but the only liquid to be used for this is oil of turpentine; for neither spirit of wine, nor any lixivium, will do with it. There is a kind called dragon's blood in tears, which, mixed with urine alone, gives a very elegant colour.

Besides these mixtures of colours and liquids, there are some colours which are to be laid on dry and unmixed. These are dragon's blood of the purest kind for a red, gamboge for a yellow, green wax for a green, common brimstone, pitch, and turpentine, for a brown colour. The marble for these experiments must be made considerably hot, and then the colours are to be rubbed on dry in the lump. Some of these colours, when once given, remain immutable; others are easily changed or destroyed. Thus the red colour, given by dragon's blood, or decoction of logwood, will be wholly taken away by oil of tartar, and the polish of the marble not hurt by it.

A fine gold colour is given in the following manner. Sal ammoniac, vitriol, and verdigris, are taken in equal quantities; white vitriol succeeds best, and all must be thoroughly mixed in fine powder.

The staining of marble to all degrees of red, or yellow, by solutions of dragon's blood, or gamboge, may be done by reducing these gums to powder, and grinding them with spirit of wine in a glass mortar. A pencil dipped in the tinctures, will make the finest traces on the marble while cold, which, on the heating of it afterwards, either on sand, or in a baker's oven, will all sink very deep, and remain perfectly distinct in the stone. It is very easy to make the ground colour of the marble red or yellow by this means, and leave white veins in it. This is to be done by covering the places where the whiteness is to remain with some white paint, or even with two or three doubles only of paper, either of which will prevent the colour from penetrating in that part. All the degrees of red are to be given to marble by means of dragon's blood alone; a slight tincture of it, without the assistance of heat to the marble, gives only a pale flesh colour. But the stronger tinctures give it yet deeper; to this the assistance of heat adds yet greatly; and finally, the addition of a little pitch to the tincture gives it a tendency to blackness, or any degree of deep red that is desired.

A blue colour may be given to marble by dissolving archil in

a lixivium of lime and urine, or in hartshorn or bone spirit; but this has always a tendency to purple, whether made by the one or the other of these ways. A better blue, and used in an easier manner, is furnished by the Canary archil. This needs only to be dissolved in water, and drawn on the place with a pencil; it penetrates very deep into the marble, and the colour may be increased by drawing the pencil wetted afresh, several times over the same lines. This colour is subject to spread and diffuse itself irregularly; but it may be kept in regular bounds, by circumscribing its lines with beds of wax, or any other such substance. It is to be observed that this colour should always be laid on cold, and no heat given, even afterwards, to the marble; and one great advantage of this colour is, that it is therefore easily added to marbles already stained with any other colours, and it is a very beautiful tinge, and lasts a long time.

This art in several people's hands has been a very lucrative secret, though there is scarcely any thing in it that has not at one time or other been published. Kircher, however, was one of the first who published any thing practicable about it. The author, meeting with stones in some cabinets, supposed to be natural, but having figures too nice and particular to be supposed to be nature's making, and these not only on the surface, but sunk through the whole body of the stones, was at the pains of finding out the artist who did the business; and, on his refusing to part with the secret on any terms, Kircher, assisted by Albert Gunter, a Saxon, endeavoured to find it out; in which they succeeded, at length, very well. Their method was this. They took aqua fortis and aqua regia, of each two ounces; sal ammoniac, one ounce; spirit of wine, two drams; about twenty-six grains of gold, and two drams of pure silver. They calcined the silver, and put it into a phial, and poured upon it the aqua fortis. They let this stand some time, then evaporated it, and the remainder appeared first of a blue, and afterwards of a black, colour. They then put the gold into another phial, poured the aqua regia upon it, and when it was dissolved, evaporated as the former. Next they put the spirit of wine upon the sal ammoniac, and let it evaporate in the same manner.

All the remainder, and many others made in the same manner from other metals, dissolved in their proper acid menstrua, are to be kept, and used with a pencil on the marble. These will penetrate without the least assistance of heat; and the figure being traced with a pencil on the marble, the several parts are to be touched over with the proper colours, and this renewed daily, till the colours have penetrated to the desired depth into the stone.

After this the mass may be cut into thin plates, and every one of them will have the figure exactly represented on both sur-

faces, the colours never spreading. The nicest method of applying these, or the other tinging substances to marble that is to be wrought into any ornamental works, and where the back is not exposed to view, is to apply the colours, and renew them so often till the figure is sufficiently seen through the surface on the front, though it does not quite extend to it. This is the method that, of all others, brings the stone to a nearer resemblance of natural veins of this kind.

It appears from the Philosophical Transactions that the art was practised by Mr. Bird, a stone-cutter at Oxford, before the year 1666; but his method is not recorded. Mr. Robert Chambers, of Minchinhampton, in Gloucestershire, discovered and practised a method of staining marble with several colours, (except blue,) which he kept a secret, and Mr. Da Costa has published an account of experiments made on several pieces of marble stained by this artist, from which he tried to discharge the stain by boiling in alkaline water, but in vain.

### ROMAN ARTIFICIAL PEARLS.

The nucleus of these pearls is formed of small pieces of fine grained alabaster. Holes are drilled through small blocks of this substance, and they are then shaped by the knife. These little blocks are afterwards coated. For this purpose the pearly and shining part of oyster and other shells, is carefully separated from the white, opaque, and rough parts, and is reduced to fine powder, which is mixed with a solution of isinglass in proof spirit, or with white transparent size of proper consistency. The beads are stuck on the points of slender pieces of bamboo, and dipped into the solution above mentioned; and then the other end of the pieces of bamboo are stuck in earth contained in pots, so as to stand upright, and at such a distance as to keep the beads from touching each other. This is performed in a warm room, and as soon as the coat is dry, the beads are again dipped in the pearly composition, and the operation is repeated until the beads are sufficiently coated. Beads so made, are extremely durable, and not so liable to injury as those made of glass bulbs, coated interiorly with the powder of the scales of the bleak, fixed with isinglass, and afterwards filled up with wax.

### *Whiting.*

This is a fine carbonate of lime, made in some places by grinding soft chalk in a mill, separating the finer particles by washing them over in water, letting the water settle, and making up the sediment into loaves; which are exposed to the air to dry.

In other places it is made from lime, by slaking it with a little water, then grinding it in a mill with water, exposing the lime-water to the air for some time, to absorb the carbonic acid

from the atmosphere, washing over the sediment, making the washed sediment into loaves, and drying them.

When made into small loaves, it is called *Spanish white:* and if in small drops, *prepared chalk*, the *creta preparata* of the apothecaries.

It is used principally as a white paint; and to saturate a superabundance of acid in any liquor.

## *Plaster of Paris.*

This is the sulphate of lime of the theorists. The raw stone called gypsum, plaster stone, or alabaster, is gotten in many places of England, as at Chelaston, near Derby, and Beacon Hill, near Newark. The former pits yield about 800 tons by the year, saleable at 5*s.* by the ton. It is ground, and used for manure, or rather as a stimulant for grass.

Gypsum is prepared for plaster of Paris in two ways, either by burning or boiling. It is burned by the masons, who use it for making floors or ceilings to houses. The operation is usually performed at night, that they may be the better able to see when the lumps become red hot, at which time they judge it to be sufficiently burned. It loses from four to six Cwt. in a ton. The parts which have been overheated acquire a yellowish cast, or a sulphurous odour, and are rejected, as causing the work to to rise in blisters. After burning, it is beaten to powder with flails, or ground in a mill, and being mixed with water, is spread upon a bed of reeds. 30 Cwt. of the raw stone are required to make twenty square yards of flooring, two inches and a half thick.

The potters and figure makers boil their plaster, by first grinding the raw stone, and then put it into a long brick trough, having a flue under it, or if a small quantity only is required, by putting it into a crucible set in a stove hole. The water escaping from the lower part of the mass, causes an apparent effervescence and decrepitation.

When the stone has not been boiled sufficiently, the plaster of Paris is a long time before it sets; and if boiled too much, it is called burnt plaster, and will not set when mixed with water.

Plaster of Paris is used by the potters to form moulds for their vessels, and also shelves on which to dry their articles; by the figure makers to form copies of statues; as also, by other artists, to form the basis of artificial marbles, or scaglioli, the different colours being given by the addition of coloured powders; and to form a cement of a smoother aspect, and finer grain than lime cements. It is also used to form certain salts, by furnishing sulphuric acid.

*Sulphas calcicus*, as it is called by Berzelius, is C: S:·2, equal to 1,714,380; and in its raw state is combined with four atoms of water, or about one-fifth of its weight, which brings it to 2,164,120: but according to Dr. Thomson, the raw stone contains only two atoms of water, and its atomic weight is 10,750, that of the boiled stone 8,500.

### *Bone Ash.*

This is a secondary product obtained in the distillation of hartshorn from bones. The still or retort being opened, the carbonaceous residuum is left to burn to whiteness.

The calcined bones thus obtained, are then ground to the required fineness, according to the use to be made of them. If for adding to lime mortar, or manure, a coarse powder is sufficient; if for polishing, under the name of *burnt hartshorn*, the powder must be very fine.

Bone ash is also used to form the vessels, or bed on which silver is refined by lead; and as it is a phosphate of lime, and cheap, it serves as the raw ingredient from which phosphoric acid and phosphorus are obtained.

### *Muriate of Lime.*

This was once celebrated as a nostrum for the stone and gravel, under the name of *liquid shell*, being made by dissolving oyster shells in spirit of salt. Its proper chemical name, before the vagaries of the significant nomenclature were introduced, was *oil of lime*.

Muriate of lime is made by dissolving chalk, marble powder, or calcareous spar, in muriatic acid.

It is only used to show the presence of carbonate of potasse, carbonate of soda, or carbonate of ammonia, in mineral waters, or acid solutions.

As it certainly has a considerable medical action on the human system, it is suspected to be the active ingredient in those medicinal waters in which its constituent principles are found, as it is impossible to suppose their well known effects are derived from the sulphate of lime, and common salt, obtained from them by evaporation.

### [*Choloride of Lime, or Bleaching Powder.*

The article on the manufacture of bleaching powder by Mr. Gray, is very brief, and by no means commensurate with the importance of the subject to American manufacturers. I shall assume, as the basis of the following observations, the article on this manufacture in Dr. Ure's Dictionary of Chemistry, with which I shall intersperse such additional information as an opportunity of inspecting several of the best works in Europe has enabled me to collect.

"A great variety of apparatus has been at different times contrived for favouring the combination of chlorine with slaked lime for the purposes of commerce. One of the most ingenious forms was that of a cylinder, or barrel, furnished with narrow wooden shelves within, and suspended on a hollow axis, by which the chlorine was admitted, and round which the barrel was made to revolve. By this mode of agitation, the lime dust being exposed on the most extensive surface, was speedily impregnated with the gas to the required degree. Such a mechanism I saw at M. M. Oberkampf and Widmer's celebrated *fabrique de toiles prints*, at Jouy in 1816. But this is a costly refinement, inadmissible on the largest scale of British manufacture. The simplest, and in my opinion, the best construction for subjecting lime powder to chlorine, is a large chamber eight or nine feet high, built of silicious sand-stone, having the

joints of the masonry secured with a cement composed of pitch, rosin, and dry gypsum in equal parts. A door is fitted into it at one end, which can be made air-tight by strips of cloth and clay lute. A window in each side enables the operator to judge how the impregnation goes on by the colour of the air, and also, gives light for making the arrangement within at the commencement of the process. As water lutes are incomparably superior to all others, where the pneumatic pressure is small, I would recommend a large valve, or door, on this principle, to be made in the roof, and two tunnels of considerable width at the bottom of each side wall. The three covers could be simultaneously lifted off by cords passing over a pulley, without the necessity of the workmen approaching the deleterious gas, when the apartment is to be opened. A great number of wooden shelves, or rather trays, eight or ten feet long, two feet broad, and one inch deep, are provided to receive the riddled slaked lime, containing generally about two atoms of lime to three of water. These shelves are piled one over another in the chamber, to the height of five or six feet, cross-bars below each keeping them about an inch asunder, that the gas may have free room to circulate over the surface of the calcareous hydrate."

The materials directed for the construction of the chamber by Dr. Ure, (silicious sand-stone,) cannot easily be procured by every manufacturer; common brick layed in the cement recommended above, and the interior surface of the chamber afterwards coated over with a mixture of pitch and rosin would in all probability answer an equally good purpose; or what would be cheaper still in this country, common pine plank, jointed and cemented together by glue, and, if need be, coated on the inside with pitch and rosin; but this last precaution would not, I think, be necessary, as we know that wood will resist the action of chlorine a long time.

"The alembics for generating the chlorine, which are usually nearly spherical, are in some cases made entirely of lead, in others of two hemispheres joined together in the middle by flanges and screws, the upper hemisphere being lead, and the under one cast iron. The first kind of alembic is enclosed for two-thirds from its bottom in a leaden or iron case, the interval of two inches between the two being destined to receive steam from an adjoining boiler. Those which consist below of cast iron have their bottoms directly exposed to a very gentle fire; round the outer edge of the iron hemisphere a groove is cast, into which the under edge of the leaden hemisphere sits, the joint being rendered air-tight by Roman or patent cement, (a mixture of lime pipe clay, and oxide of iron, separately calcined and reduced to a fine powder.) In this leaden dome there

are four apertures, each secured by a water lute. The first opening is about ten or twelve inches square, and is shut with a leaden valve, with incurvated edges, that sit in the water channel at the margin of the hole. It is destined for the admission of a workman to rectify any derangement in the apparatus of rotation, or to detach hard concretions of salt from the bottom. The second aperture is in the centre of the top. Here a tube of lead is fixed, which descends nearly to the bottom, and down through which the vertical axis passes, to whose lower end the cross-bars of iron or wood, sheathed with lead, are attached, by whose revolution the materials receive the proper agitation for mixing the dense manganese with the sulphuric acid and salt. The motion is communicated either by the hand of a workman applied from time to time to a winch at top, or it is given by connecting the axis with wheel-work impelled by a stream of water, or a steam engine. The third opening admits the syphon-formed funnel, through which the sulphuric acid is introduced; and the fourth is the eduction pipe."

The distillation of chlorine by the direct application of fire to the alembic or retort, is objected to by some manufacturers, on the ground that more water would in that case be driven over with the chlorine than there would be by the heat of ordinary steam; that is, on the supposition that more heat would be applied, and it would be very difficult to regulate a fire so as not at any time to exceed the heat of boiling water: a still more formidable objection to the direct use of fire in this distillation is the tendency of the materials to effervesce and boil over at a temperature much above 212°. From one or both of these causes manufacturing chemists seem every where to have fallen into the use of steam heat for this purpose. A wooden case, or *jacket*, as it is commonly called, is preferable to an iron one on account of its bad conducting power; but if iron be preferred for its greater durability, it should be imbedded in tan, pulverised charcoal, or some other non-conducting substance.

"Manufacturers differ much from each other, in the prepation of their materials for generating chlorine. In general, 10 cwt. of salt are mixed with from 10 to 14 cwt. of manganese, to which mixture, after its introduction into the alembic, from 12 to 14 cwt. of sulphuric acid, are added in successive portions. That quantity of the oil of vitriol must, however, be previously diluted with water, till its specific gravity becomes about 1·650. But indeed this dilution is seldom actually made, for the manufacturer of bleaching powder almost always, prepares his own sulphuric acid for the purpose, and therefore carries its concentration no higher than the density of 1·650, which from my table of sulphuric acid, indicates one-fourth of

its weight of water, and, therefore, one-third more of such acid must be used."

The diversity of practice among the manufacturers of this article, is partly attributable to the great difference observed in the quality of the oxide of manganese. Dr. Warwick, a very scientific chemical manufacturer of Manchester, directs as the best proportions 10 cwt. muriate of soda, 8 cwt. oxide of manganese, and 14 cwt. oil of vitriol. Mr. Tennant, of Glasgow, formerly used equal parts of these materials, but I believe Dr. Ure is supposed in the foregoing statement to give the proportions used by Mr. Tennant at the time he wrote, (1824.) The value of the oxide of manganese for the production of chlorine, depends directly upon the proportion of oxygen it contains, or, more properly, upon the proportion of real peroxide contained in any given specimen.

"The fourth aperture, I have said, admits the eduction pipe. This pipe is afterwards conveyed into a leaden chest, or cylinder, into which all the other eduction pipes" (from other alembics) "terminate. They are connected with it simply by water lutes, having a hydrostatic pressure of two or three inches. [This hydrostatic pressure is entirely unnecessary.] In this general *diversorium*, the chlorine is washed from adhering muriatic acid, by passing through a little water in which each tube is immersed; and from this the gas is led off by a pretty large leaden tube; into the *combination room.* It usually enters in the top of the ceiling, whence it diffuses its heavy gas equally around.

"Four days are required, at the ordinary rate of working, for making good marketable bleaching powder. A more rapid formation would merely endanger an elevation of temperature, productive of muriate of lime, at the expense of the bleaching quality. But skilful manufacturers here use an alternating process. They pile up first of all the wooden trays only in alternate shelves in each column. At the end of two days, the process is intermitted, and the chamber is laid open. After two hours the workman enters, to introduce the alternate trays covered with fresh hydrate of lime, and at the same time rakes up thoroughly the half-formed chloride in the others: the door is then secured, and the chamber after being filled for two days more with chlorine, is again opened, to allow the first set of trays to be removed, and to be replaced by others, containing fresh hydrate, as before. Thus the process is conducted in regular alternation; thus, to my knowledge, very superior bleaching-powder is manufactured, and thus the chlorine may be suffered to enter in a pretty uniform stream. But for this judicious plan, as the hydrate advances in impregnation, its fa-

culty of absorption becoming diminished, it would be requisite to diminish proportionably the evolution of chlorine, or to allow the excess to escape, to the great loss of the proprietor, and, what is of more consequence, to the great detriment of the health of the workmen."

The foregoing arrangement, although very ingenious, is liable to a very serious objection; the heat produced by the union of the chlorine with the fresh portion of lime, is such, as to retard in a great degree the union of the gas with the half-saturated lime, and even, for a time, to expel a portion of the chlorine already united with it; so that it is very doubtful if there is any advantage, whatever, gained by this alternation, of strata in different states of impregnation. The object aimed at is better accomplished, and the inconvenience avoided by a more recent contrivance:—the use of two chambers instead of one, connected together by a large iron pipe; the gas is conducted into one or the other, in the first instance, according to their respective states of saturation. To explain the operation we will designate the chambers by A and B. At the commencement of the operation, the shelves or trays of both chambers are filled with fresh hydrate, and the gas is conducted first into A, where a large proportion of it is absorbed, and the remainder escapes into the chamber, B, and is also absorbed; the distillation is continued till the lime in the first chamber is saturated; the process is there intermitted; the powder from this chamber is withdrawn, and the trays replenished with fresh lime; the distillation is then renewed, and the gas is conducted first into the chamber, B, and secondly, into A. When the lime in B has become perfectly saturated, it is removed, and this chamber is in turn replenished with new lime-powder; and when the distillation is renewed, the course of the gas is again reversed, and enters first the chamber A, and so on; the chambers are alternately filled and emptied, as long as the manufacture is carried on. The object and effect of this arrangement is obvious,—to bring the strongest, or densest gas in contact first with that portion of the lime, which is nearest the point of saturation, (for we must suppose, that the lime absorbs the gas with an avidity in an inverse ratio to its approximation to the saturated point,) and at the same time create such a demand for the uncondensed chlorine, by the fresh lime in the adjoining chamber, as shall prevent any loss. The current of gas from the chamber, into which the gas first enters to the second, is in a direction to prevent the heat generated by the union of the chlorine with the fresh lime, from retarding the combination of the chlorine with the partially saturated powder in the other chamber. An iron tube is preferable to a

curved one, for connecting the chambers, because the temperature of the gas will by that means, be reduced more by the external air; but this direction is not very important.

The alembics employed for this purpose, may have a capacity of about one hundred gallons; larger ones are inconvenient, on account of the difficulty of stirring so large a mass of dense materials: many manufacturers use much smaller ones. They should not be filled much more than half full, owing to the swelling and effervescence, which occurs in the distillation. The number of the alembics must depend, of course, on the size of the chambers, and even then no exact rule can be laid down; the more they are employed, the more expeditious will be the process. I should allow 100 gallons' capacity of alembic for every 1000 cubic feet of chamber room, but much less capacity in the retort will answer, and less is generally used.

As some gas will always unavoidably escape from the chambers in this operation, and as a matter of course, during the ventilation of them, it is better that they should not be enclosed; an open shed, with a roof projecting over the chambers, a distance of six or eight feet, is all that is necessary; indeed, the exposure to the open air is beneficial on another account,—the atmosphere of the chamber within is thereby kept at a somewhat lower temperature, which is more favourable to the union of the chlorine and lime.

The alembics should be made of the purest new lead, and, if not cast, (which is the best plan) the seams should be soldered with lead also. This gas acts with great avidity upon tin, and, therefore, neither old lead, which is liable to be impregnated with tin, sheet lead soldered, nor pewter, can be admitted into their construction.

"The manufacturer," continues Dr. Ure, "generally reckons on obtaining from one ton of rock-salt, employed as above, a ton and a half of good bleaching powder. But the following analysis of the operation will show that he ought to obtain two tons.

Science has done only half her duty when she describes the best apparatus and manipulations of a process. The *maximum* produce should be also demonstrated, in order to show the manufacturer the perfection, which he should strive to reach, with the *minimum* expense of time, labour and materials. For this end I instituted the following researches:—I first examined fresh commercial specimens of bleaching powder; 100 grains of these afforded from 20 to 28 grains of chlorine. This is the widest range of result, and it is undoubtedly considerable; the first being to the second as 100 to 71. The first yielded by saturation with muriatic acid, 82 grains of chloride of calcium, equivalent to about 41 of lime. It contained besides

26 *per cent.* of water, and a very little common muriate ready formed. On heating such powder in a glass apparatus, it yielded at first a little chlorine, and then oxygen tolerably pure. The bulk of chlorine did not exceed one-tenth of the whole gaseous product. Of the recently prepared powder of another manufacturer, 100 grains were found to give, by solution in acid" (the muriatic,) "23 grains of chlorine, and there remained after evaporation and gentle ignition, 92 grains of muriate of lime, equivalent to about forty-six of lime. Supposing this powder to have been nearly free from muriate, (and the manufacturers are anxious to present the deliquescent tendency which this introduces,) we should have its composition as follows:—

| | | | |
|---|---|---|---|
| Chlorine | 23 | | 3·5 |
| Lime | 46 | one atom 3·5 + 2 = | 7·0 |
| Water | 31 | | |
| | 100 | | |

"This powder being well triturated with different quantities of water at 60°; yielded filtered solutions of the following densities at the same temperature:

| | Sp. gr. |
|---|---|
| 95 water + 5 bleaching powder | 1·0245 |
| 90 + 10 | 1·0470 |
| 80 + 20 | 1·0840 |

"The powder left on the filter, even of the second experiment, contained a notable quantity of chlorine, so that the chloride is but sparingly soluble in water; nor could I ever observe that partition occasioned by water in the elements of the powder of which Mr. Dalton and Mr. Welter speak. Of the solution 80 + 20, 500 grains, apparently corresponding to one hundred grains of powder, gave off by saturation with muriatic acid, 19 grains of chlorine, and the liquid, after evaporation and ignition, afforded 41·8 grains of chloride of calcium, equivalent to 21 of lime. Here 4 *per cent.* of chlorine seem to have remained in the undissolved calcareous powder, which, indeed, on examination yielded about that quantity. But the dissolved chloride of lime consisted of 19 chlorine to 21 of lime; or of 4·5 atoms of the former to almost exactly 5 (which is no atomic proportion,) of the latter. The two-thirds of a grain of lime existing in the lime water, in the 500 grains of solution, will make no essential alteration on the statement. Now the above bleaching powder must have contained very little muriate of lime, for it was not deliquescent. Being thus convinced, both by examining the pure chloride of my own preparation," (alluding to a previous experiment not here cited,) "as well as that of commerce, that no atomic relations are to be observed in its constitution, for reasons already as-

signed, I ceased to prosecute any more researches in that direction.

"When we are desirous of learning minutely the proportion between the chloride and muriate of lime in bleaching powder, pure vinegar may be used as the saturating acid. Having thus expelled the chlorine, we evaporate to dryness, and ignite when the acetate of lime will become carbonate, which will be separated from the original muriate by solution and filtration.

"I have found, on trial, the method by carbonic acid to be exceedingly slow and unsatisfactory. After passing a current of this gas for a whole day through the chloride, diffused in tepid water, I found the liquid still to possess the power of discharging the colour very readily from litmus paper. But the doctrine of equivalents furnishes a very elegant theorem with acetic acid, whose conveniency and accuracy I have verified by experiment. An apparently complex, and very important problem of practical chemistry, is thus brought within the reach of the ordinary manufacturer. Since common fermented vinegar is permitted by law to contain a portion of sulphuric acid, which avarice often leads the retailer to increase, we cannot employ it in the present research. But strong vinegar prepared from pyroligneous acid, such as that with which Messrs. Turnbull and Ramsay have long supplied the London market, being entirely free from sulphuric acid, is well adapted to our purpose. With such acid, contained in a phial, fully saturate a given weight (say 100 grains) of the bleaching powder, contained in a small glass matrass, applying a gentle heat at last, with inclination of the mouth of the vessel to expel the adhering chlorine. Note the loss of weight due to the disengagement of the gas. (If carbonic acid be suspected to be present, the gas may be received over mercury.) Evaporate the solution, consisting of acetate and muriate of lime, to dryness, by a regulated heat, and note the weight of the mixed saline mass. Then calcine this at a very gentle red heat till the acetic acid be all decomposed. Note the loss of weight. We have now all the *data* requisite for determining the proportion of the constituents without solution, filtration, or precipitation by re-agents.

"Problem I.—To find the lime originally associated with the chlorine, or at least *not* combined with the muriatic acid, and therefore converted into an acetate. *Rule.*—Subtract from the above loss of weight its twenty-fifth part, the remainder is the quantity of lime taken up by the vinegar.

"Problem II.—To find the quantity of muriate of lime in the bleaching powder. *Rule.*—Multiply the above loss of weight by 1·7, the product is the quantity of carbonate of lime in the calcined powder, which being subtracted from the total weight of the residuum, the remainder is of course the muriate of lime. We know now the proportion of chlorine lime and

muriate of lime in 100 parts; the deficiency is the water in the bleaching powder. Thus, for example, I found 100 grains of a commercial chloride some time kept, to give off 21 grains of chlorine, by solution in acetic acid. The solution was evaporated to dryness: of saline matter 125·6 grains were obtained, which, by calcination, became 84·3, having thus lost 41·3 grains. But $41{\cdot}3 - \frac{41{\cdot}3}{25} = 39{\cdot}65 =$ lime present, uncombined with muriatic acid; and $41{\cdot}3 \times 1{\cdot}7 = 70{\cdot}2 =$ the carbonate of lime in the residuary 84·3 grains of calcined salts. Therefore $84{\cdot}3 - 70{\cdot}2 = 14{\cdot}1 =$ muriate of lime. Now by dissolving out the muriate of lime, and evaporating, I got 14 grains of it, and the remaining carbonate was 70·3 grains. Hence, this powder consisted of chlorine 21, lime 39·65, muriate of lime 14, and water $25{\cdot}35 = 100$.

"Sulphate of indigo, largely diluted with water, has long been used for valuing the bleaching powder of chloride of lime; and it affords, no doubt, a good comparative test, though from the variableness of indigo it can form no absolute standard. Thus I have found three parts of indigo, from the East Indias, to saturate as much bleaching powder as four parts of good Spanish indigo.

"Mr. Wilter's method is the following:—He prepared a solution of indigo in sulphuric acid, which he diluted, so that the indigo formed one-sixteen hundredth of the whole. He satisfied himself by experiments, that 14 litres (854·4 cubic inches, or 3·7 wine gallons, English) of chlorine, which weigh 651½ English grains, destroyed the colour of 164 litres of the above blue solution. He properly observes, that chlorine discolours more or less of the tincture, according to the manner of proceeding, that is, according as we pour the tincture on the aqueous solution of chlorine, and as we operate at different times, with considerable intervals; if the aqueous chlorine, or chloride solution, be concentrated, we have the *minimum* of discoloration, if it be very weak, the *maximum*. He says that a solution of indigo, containing about one-sixteen hundredth part, will give constant results to nearly one-fortieth; and to greater nicety still, if we dilute the chlorine solution, so that it shall amount to nearly one-half the volume of the tincture, which it can dissolve; if we use the precaution to keep the solution of chlorine and the tincture in two separate vessels; and, finally, to pour both together into a third vessel. We should, at the same time, make a trial on another sample of chlorine, whose strength is known, in order to judge accurately of the hue. On the whole, he considers that fourteen measures of gaseous chlorine can discolour one hundred and sixty-four measures of the above indigo solution, being a ratio of nearly one to twelve. The advantage of the very dilute tincture obviously consists in

this, that the excess of water condenses the chlorine separated from combination by the sulphuric acid, and confines its whole efficacy to the liquor; whereas, from concentrated solutions, much of it escapes into the atmosphere. Though I have made very numerous experiments with the indigo test, yet I never could obtain such consistency of result as Mr. Welter describes; when the blue colour begins to fade, a greenish hue appears, which graduates into brownish yellow by imperceptible shades. Hence, an error of one-twentieth may readily be allowed, and even more, with ordinary observers.

"When a mixture of sulphuric acid, common salt, and black oxide of manganese, are the ingredients used, as by the manufacturer of bleaching powder, the absolute proportions are—

| | | | |
|---|---|---|---|
| 1 atom muriate of soda | 7·5 | 29·70 | 100·0 |
| 1 atom peroxide of manganese | 5·5 | 21·78 | 73·3 |
| 2 atoms oil of vitriol 1·846 | 12·25 | 48·52 | 163·3 |
| | 25·25 | 100·00 | |

And the products ought to be—

| | | | |
|---|---|---|---|
| Chlorine disengaged | 1 atom | 4·5 | 17·82 |
| Sulphate of soda | 1 | 9·0 | 35·64 |
| Protosulphate of manganese | 1 | 9·5 | 37·62 |
| Water | 2 | 2·25 | 8·92 |
| | | 25·25 | 100·00 |

"These proportions are, however, very different from those employed by many, nay, I believe, by all manufacturers; and they ought to be so on account of the impurity of their oxide of manganese. Yet, making allowance for this, I am afraid that many of them commit great errors in the relative quantities of their materials.

"From the preceding computation, it is evident that one ton of salt, with one ton of the above native oxide of manganese, properly treated, would yield 0·59 of a ton of chlorine, which would impregnate 1·41 tons of slaked lime, producing two tons of bleaching powder, stronger than the average commercial specimens; or, allowing for a little loss, which is unavoidable, would afford two tons of ordinary powder, with a little more slaked lime."

Directions have also been published by M. Gay Lussac for testing the strength of bleaching powder, but they do not differ materially from those of Mr. Welter. I have found this method, in the main, sufficiently correct for practical purposes. To obviate the objections to it growing out of the variable strength of indigo, it is only necessary for the manufacturer, or consumer, of the article to prepare a considerable quantity of the solution of indigo at once, and when that stock is nearly

exhausted to make another solution and to adjust its strength accurately with the first by the addition of more indigo, or dilution with water, as the case may require; but this will seldom be required, for a single ounce of indigo, dissolved in the sulphuric acid, will be sufficient for making some thousands of trials. Not having access to Mr. Welter's paper on the subject, I do not clearly understand the meaning, or practicability, of the precaution to "keep the solution of chlorine and the tincture (meaning the sulphate of indigo) in two separate vessels; and, finally, to pour both together into a third vessel:" this appears to be settling the question beforehand, which we wish to determine by experiment; but were it possible to determine *a priori* the exact amount of indigo, which the solutions of chlorine would discolour under the most favourable circumstances; this manner of mixing must produce very variable results where they ought to be precisely similar. Gay Lussac found that very different results were produced according as the sulphate of indigo was turned upon the chloride solution, or the reverse; and also according as the operation was performed quickly, or otherwise. The best method is to use a very dilute solution of the chloride of lime, and add the sulphate of indigo to it drop by drop; a nearer approximation to perfect uniformity in the manner of the operation may be obtained in this than in any other way. In other respects the manipulations of Mr. Welter are well calculated to secure the object. The reader will find directions for preparing the sulphate of indigo under the head of *Saxon Blue* in this work.

### *Bleaching Liquor.*

This term is applied by bleachers to a solution of chloride of lime formed by diffusing lime through a body of water, and then saturating the mixture with chlorine produced in the same manner as already described. It is a more convenient and economical method of procuring the chloride of lime when wanted on the spot where it is produced; and the Lancashire, as well as many of the American, bleachers prepare it for themselves.

Fig. 105, although designed for another purpose, will give a general idea of the entire apparatus, *a*, *b*, *c*, *d*, *e* the distillatory part, (which is, however, considerably different from that recommended in the preceding article,) *g*, the intermediate vessel of water for absolving the muriatic acid, which distils even through the pipe *f* and *h*, the tube conveying the purified chlorine to the large tub containing the milk of lime; no part of the interior apparatus of this tub is necessary for this purpose except the upright central shaft and the arms attached to it for keeping the lime suspended in the water by frequent, or continual, agitation during the absorption of the gas. The tube *h*, instead of passing so near the bottom of the tub, as in the plate, need only dip five or six inches under the surface of the liquid. This cistern, or tub, should be closed at top, leaving only an aperture, or man-hole, through which the workmen may descend to clear out the cistern from time to time, and rectify any derangement of the cistern, or apparatus within; this man-hole to be closed during the ope-

ration of impregnation of the lime. The intermediate vessel, *g*, is not essential, as the formation of a little muriate of lime in the liquor is no ways objectionable.

A very general impression prevails among the bleachers in Lancashire, that a given amount of the materials for producing chlorine when expended in bleaching liquor will have more blanching effect than when appropriated to the formation of bleaching powder. The value of the bleaching liquor compared with the powder is considered as 13 to 10. The difference is, I think, overrated; yet it is probably considerable. It may be accounted for from two circumstances, 1st, that in the manufacture of bleaching liquor, probably less chlorine is wasted or lost, and 2d, that more is actually produced:—in the manufacture of the powder, it is impossible with every precaution to prevent the escape of some gas; and after it is fairly combined with the lime, there is a constant tendency to decomposition and loss; whereas in the manufacture of the bleaching liquor, if the process be well conducted, there is very little loss of chlorine, and, if an excess of lime be allowed, the escape of gas and decomposition of the chloride is very trifling; the distillation may be conducted at a higher temperature in the manufacture of the liquor, as no inconvenience or injury will accrue from driving over watery vapour and a little more muriatic acid, and more chlorine will be produced. That the decomposition of the materials for distilling chlorine is far from being complete when the process is conducted at the temperature of boiling water, is very certain from the fact that in calcining the bleachers' residuum in a reverberatory furnace, chlorine continues to be emitted copiously even at, or approaching, a red heat. In manufacturing the bleaching liquor, it is, therefore, preferable to distil the chlorine by the direct application of fire to the bottom of the alembic. The heat should be very moderate at first to prevent a too violent action and effervescence, but urged strongly towards the close of the process.

The theory of the production of chlorine by the foregoing process is this;—a part of the sulphuric acid combines with the soda of the salt and displaces the muriatic acid; muriatic acid is composed of chlorine and hydrogen; the hydrogen combines with the oxygen of the peroxide and deutoxide of manganese forming water, and the chlorine is liberated in its elastic form; the remaining portion of the sulphuric acid unites with the protoxide of manganese forming a sulphate of manganese; a small part of the muriatic acid also combines with the protoxide of manganese, producing a muriate of that metal. The *caput mortuum* remaining in the alembic after distillation consists then of sulphate and muriate of manganese and sulphate of soda; and

since the manganese is very variable in its quality, it is rarely that the salt, acid, and oxide are so proportioned as that there shall be no excess of either even if the decomposition could be otherwise complete: there is therefore generally mixed with the foregoing products more or less of one or more of the original compounds, sulphuric acid, muriate of soda, and peroxide of manganese, besides the ordinary impurities of the latter ingredient.

Chemists are divided in opinion as to the exact constitution of bleaching powder. Mr. Dalton, Dr. Thomson, M. Welter, and, I believe, Gay Lussac, regard it as a sub-chloride or di-chloride of lime, in which thirty-six parts or one atom of chlorine are united with fifty-six parts or two atoms of lime. They consider that on mixing this di-chloride with water one atom of lime is deposited, and a real chloride is formed. Dr. Ure, on the contrary, as appears from the article quoted already, denies that the elements of this compound constitute a proper atomic combination; practically this question is of no importance to the bleacher, for in either case, it is agreed that the bleaching liquor must be the same.

The manufacturer judges of the strength of his bleaching liquor for the most part by its specific gravity. It is a good rule to stop the distillation of chlorine when it has acquired a specific gravity of 1.025, or 5° on Tweedale's hydrometer at 60° Ft.

The cascades of M. Clement described under the article "oxy-muriatic acid" of this work—(vide Fig. 107 and the description) are not found of any practical utility, on the large scale of manufacture of bleaching powder and liquor. What he calls the *absorbing* cascade is not required; and the *productive* cascade is liable to a very serious objection.—The distillation goes on very well for a time, but after a while, the lumps of manganese become so coated with the muriate of manganese as to prevent the formation of chlorine altogether, and the muriatic acid passes through it unchanged.

Dr. Warwick has proposed to obviate this difficulty by inserting a false perforated floor or grate two or three inches from the bottom of the cascade, upon which the oxide of manganese may rest, and through which the water may drain and be drawn off as shown in the plate; and to get rid of the muriate of manganese more effectually, he recommends a third aperture in the centre of the top of the vessel to be kept closed for the most part during the distillation, but through which boiling water may be poured from time to time to filter through and dissolve out the incrusting muriate: but even with this alteration, this apparatus will hardly come into use among practical manufacturers. It requires the exercise of far more judgment, skill, and attention,

to make it answer well, than is generally met with among such persons as usually have the immediate charge of these processes.

As the economy and success of chemical manufactures depends very much upon the disposition of the residuum after the various distillations, the English manufacturing chemists have exercised themselves a good deal in endeavouring to turn the bleachers' residuum, as the matters remaining in the retorts after this distillation are usually called, to a profitable account. The two following articles are the only ones that will reward the American manufacturer, and the demand for these is too limited to appropriate but a small portion of the *caput mortuum* in any considerable manufactory. They are, however, worthy of the manufacturer's attention.]

### [*Sulphate of Manganese.*

To prepare this salt, calcine the bleachers' residuum at a red heat in a reverberatory furnace to drive off the excess of acid and the chlorine. This process will be expedited by stirring and raking the materials occasionally during the operation, which may last from two to three hours according to the strength of the heat and the amount of the residuum operated on.

After the calcination dissolve the materials in three or four times their weight of water in a large cast-iron vessel, and when the brown oxide of manganese and other insoluble matters have subsided, decant, or draw off, the clear liquor into another cast-iron vessel until the crystals of the salts of manganese are copiously precipitated. Scoop the crystals out with an iron ladle, and put them into a wicker basket over the boiler to drain. Continue boiling until the crystals begin to be coloured and evidently not so pure as at first. Then draw off the clear hot liquor into shallow leaden vessels to cool. There will be a copious deposite of Glauber's salts. The mother water may then be poured back into the boiler and the process repeated, after which the sulphate of soda will become troublesome, and the salts of manganese will be liable to be much contaminated with it; indeed where there is a manufactory of bleaching powder, the product from the first operation will be quite sufficient for almost any demand, and it will scarcely ever be worth while to repeat the process on the mother water. The Glauber's salts alone would scarcely pay for the fuel and labour of evaporation, though this must depend much upon the price of fuel when the operation is carried on.

The sulphate of manganese procured in this way, contains a small portion of the muriate of manganese, which does not, however, affect its value for the purposes of the calico printer; by whom, I believe, it is exclusively used. It is employed to

produce a bronze colour, and is better known in commerce by the name of *brown salts.* Some printers prefer the acetate of manganese, which is readily formed by double decomposition of the sulphate of manganese and the acetate of lead, or more cheaply by the use of the pyrolignate, (crude acetate) of lime.]

[*Sulphuret of Antimony with Soda (or Orange Crystals.)*

Mix with the bleachers' residuum, small coal, (sea coal,) or *slack* and slaked lime in the following proportions;

2 Parts of the residuum;
2 Parts of coal; and
½ Part of slaked lime:

Mix these substances well together, and decompose them at a red heat in a reverberatory furnace. Stir the mixture till the flame begins to cease, and the materials have assumed a semi-fluid state; then draw off into shoal iron pans capable of holding half cwt. each. Break up this product when cold, which is the rough sulphuret of soda, mixed with the oxide, and, probably, the sulphuret of manganese; put it into a leach tub; the bottom of which is covered first with brushwood or broken bricks, and afterwards with straw; pour upon the materials hot water, and dissolve out the sulphuret of soda. Concentrate the clear filtered liquor to 30° on Tweedale's hydrometer, and when boiling hot, add crude antimony by degrees in powder till the effervescence nearly ceases. As soon as the liquor has dissolved, all the antimony it will take up, add for every hundred weight of the antimony from 20 to 28lbs. of rough brimstone in powder, or sufficient to raise the specific gravity to 38° T. Let the liquor stand in the boiler two hours, and then decant it into earthen pans and the crystals will shoot in twelve hours. Pour the mother water back into the boiler and repeat the process.

The brightness of the colour depends upon the quantity of sulphur, therefore, more or less may be used according to the shade required.

This compound was first introduced into calico printing by an ingenious colour mixer by the name of Mercer; and was first introduced as an article of commerce in the crystalline form by Dr. Warwick of Manchester. It produces a very bright, but fugitive yellow.

When the mother water has been used several times, Glauber's salts will crystallize; the liquor may then be boiled away, and the dry product mixed with fresh residuum and the calcination, &c., repeated.

It is scarcely necessary to add, that sulphate of soda alone

will answer in this manufacture all the purposes of the bleachers' residuum. The sulphate of soda remaining in the retort after the distillation of muriatic acid, will answer equally well for this purpose; but as this last article can be converted into rough barilla, or Glauber's salts, articles of some value, it is better to use the bleachers' residuum when we have it, as it would in many instances be otherwise thrown away as useless. When the residuum from the distillation of muriatic acid is used, one half the quantity to the proportions of coal and lime already mentioned, will be sufficient. Charcoal will answer instead of sea-coal where the price will admit of its employment.]

## BARYTES.

This alkaline earth was long confounded with lime, but at last distinguished by the name of *ponderous earth*, its specific gravity being nearly double that of lime, or the generality of earths. The present name has been spelled *barote*, *barites*, *barita*, *baryta*, and even *barogeum*.

Its heaviness led early to the idea of its being a metallic oxide, or calx, which, however, is not yet thoroughly demonstrated, but only presumed. Berzelius considers it as Ba:, and its atomic weight 1,913,86; Thomson, as Ba·, equal to 9,750.

Barytes is obtained by heating nitrate of barytes in a crucible; but is of no use.

Common barytes is obtained by evaporating the barytes water prepared from the carbonate, but this contains water; it however, especially if crystallized, is convenient to prepare barytes water extemporaneously, for the purpose of examining mineral waters.

### *Barytes Water.*

Dr. Henry recommends Pelletier's process for making it. The carbonate of barytes found in various parts, is powdered, and mixed up with an equal measure of wheat flour, and a little water, into a ball. A crucible is then filled one-third of its height with charcoal dust, the ball placed on this bed, and covered with more charcoal dust. A cover being luted on the crucible, it is exposed to a most violent heat for two hours. When cold the ball is to be flung into water, the barytes will dissolve, and the solution is to be filtered.

Barytes water is used to detect the presence of carbonic acid in mineral waters. It is also used to discover sulphuric acid in any liquid, as it forms a sediment which is not soluble in muriatic acid.

*Nitric solution of barytes.*
*Muriatic solution of barytes.*
*Acetic solution of barytes.*

These are also called respectively, *nitrate of barytes*, *muriate of barytes*, and *acetate of barytes*, and are prepared by dissolving the natural carbonate of barytes in the respective acids.

They are used to discover the presence of sulphuric acid in mineral waters.

## STRONTIA.

This earthy alkali, called also *strontites*, and *strontian*, is only used, when combined with nitric acid, in fire works.

### *Nitrate of Strontia,*

Is prepared by dissolving the native carbonate of strontia in weak nitric acid, evaporating the solution, and crystallizing it.

This salt is used in fire works, to which it gives the property of tinging all the surrounding bodies of a blood red colour; and hence employed in theatres, when conflagrations are represented: the formula is described in p. 340.

## QUININE,

Called also, *quina*, is an alkaline substance, producible from yellow bark and red bark; the combination of which, with sulphuric acid, is at present much used by the medical faculty.

### *Sulphate of Quinine.*

For obtaining this medicine, two Troy pounds of yellow bark in powder, is boiled in two wine gallons of water, mixed with two ounce measures of oil of vitriol, the decoction is strained through a linen cloth; the residue on the filter boiled again, with a fresh quantity of soured water, and filtered. To the decoctions mixed together is gradually added powdered lime, until the decoction has become slightly alkaline, and of a dark colour: which generally requires about half a pound of lime. A brown flaky sediment falls down, which is separated by straining through a linen cloth, washed with a little cold water, and then dried.

When this sediment is dry, it is to be digested in several successive portions of spirit of wine, with a moderate heat, for some hours, until all the bitterness is extracted. The several portions of spirit are then mixed, and distilled with a gentle heat until three-quarters of the spirit has passed over the helm. The residue in the body or matrass is a brown thick substance, covered with a bitter alkaline liquid, which is to be poured off, saturated with weak sulphuric acid and boiled down with a little ivory black; the liquor is then filtered while hot; on cooling, the sulphate of quinine crystallizes, and the crystals are to be dried on filtering paper.

The brown thick substance is boiled in a small quantity of water, slightly soured with oil of vitriol, which changes a considerable portion of it into sulphate of quinine.

Two pounds of yellow bark generally yields from five to six apothecaries' drams of the sulphate of quinine, in crystals of a satiny and pearly lustre.

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There is another mineral alkali called lithine, of no use at present; and many other alkalies of vegetable origin, which have not hitherto been used. It is to these alkalies that the greater part of the poisonous substances of the vegetable kingdom owe their power.

## EARTHS.

Under the name of earths, chemists have usually ranked those bodies which are scarcely, if it all, soluble in water, not capable of burning, nor having any action upon the blue or red colours of vegetables. At present they are considered as the oxides of certain metals.

Except silica, which is found pure in rock crystal, and nearly so in quartz, and some fine white sands, all the other earths are naturally combined together in a variety of proportions and admixtures; and the resolution of these combinations form the occupation of a numerous class of chemists; these analyses having within the last fifty years succeeded to the more useful researches on the fusibility or infusibility of the natural earths and stones, and their other chemical properties, as begun by Imperatus, and continued by Hiærne, Wallerius, and especially Pott in his Lithogeognosie.

The accurate analysis of earths and stones, like that of mineral waters, requires considerable knowledge of the theory of chemistry; but a shrewd guess can be given of their contents by examining them by the blow-pipe, as mentioned in p. 107. Or a small portion may be dissolved in nitro-muriatic acid, and the solution being largely diluted, examined in the manner of mineral waters. But as some earths and stones are not soluble in this acid in their raw state, some of them must be prepared for dissolving by being melted with some appropriate fluxing powder, such as pure potasse in a silver crucible; calcined borax for stones which principally consist of alumine; boracic acid for those that contain potasse or soda; and nitrate of lead, mixed with half its weight of carbonate of lead, for those that contain silica united with potasse or soda. The flux being washed out, the stone will then dissolve in the acid.

### SILICA, OR SILICEOUS EARTH.

This earth was originally distinguished by the name of *vitrifiable earth*, as it forms a transparent glass with the fixed alkalies, potasse or soda. It has also been called *flint earth*.

This species of earth is conceived to be the oxide of a metal called *silicium*, but which others call *silicon*. Although this substance unites with iron, it differs so very considerably from the bodies usually called metals, that it can scarcely be considered as belonging to the same class.

### *Gun Flints.*

The great importance of gun flints in warfare requires peculiar notice to be taken of their manufacture, especially as it is very simple.

The masses of flint which are best fitted for this purpose, are of a convex surface, approaching to globules. The knobbed and branched flints are commonly full of imperfections. The colour should be uniform in the same nodule, and may vary from honey yellow to a blackish brown. The fracture should be smooth and equal, and the fragments slightly conchoidal; and the transparency should be such as to allow letters to be distinguished through a thickness of one forty-eighth of an inch when laid close to the paper.

Fig. 118, represents the whole apparatus of this manufacture, in which four tools are necessary; *a*, an iron hammer with a rectangular head, a handle seven or eight inches long, and not exceeding two pounds in weight; *e*, is the head of this instrument. *B*, a hammer of well hardened steel, with two points, a handle seven inches long, and from ten to sixteen ounces in weight; the handle must pass through in such a manner that the two points may be nearer the hand of the workman than the centre of gravity of the mass; the head of this hammer is represented at *f*. *C*, a round hammer, like a solid wheel, or the section of a cylinder, as shown at *g*, two inches and a quarter in diameter, and not exceeding twelve ounces in weight; it is made of steel, not hardened, and has a handle six inches long, which passes through a square hole in the centre. *D*, is a chisel, tapering and bevelled at both ends. It should be made of steel, not hardened, and six, seven, or eight inches long, and two inches wide; this is set on a wooden block, which is also used as a bench for the workman. Besides these tools, a file is necessary for restoring the edge of the chisel.

The workman seated on the ground, places the nodule of flint on his left thigh, and applies slight strokes with the square hammer, to divide it into smaller pieces of about a pound and a half each, with broad surfaces and almost even fracture.

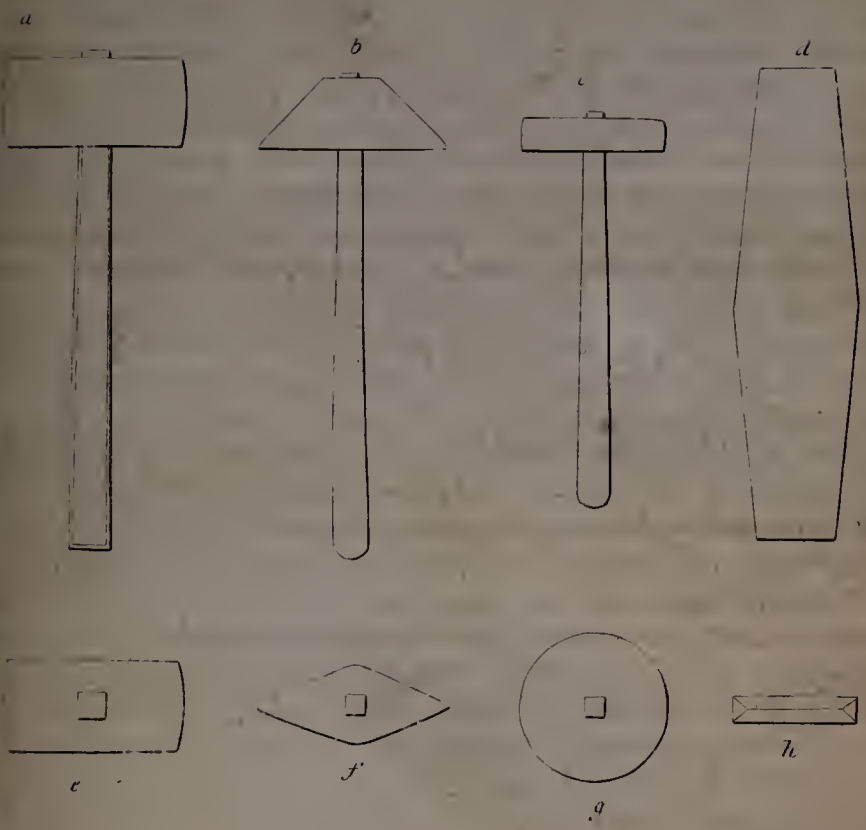
He then holds the piece of flint in his left hand, not supported, and strikes with the pointed hammer, *b*, on the edges of the great planes produced by the first breaking, by which means the white coating of the flint is removed in the form of small scales, and the mass of the flint itself laid bare in the manner represented, at *i*. After which he continues to chip off similar scaly portions from the pure mass of the flint. These scaly portions are nearly one inch and a half wide, two inches and a half long; and their thickness in the middle is about one-sixteenth of an inch. They are slightly convex below, and consequently leave in the part of the flint from which they were separated, a space slightly concave, longitudinally bordered by two rather projecting straight lines, or ridges, as at *k*. These ridges, produced by the separation of the first scales, must naturally constitute nearly the middle of the subsequent piece; and such scales alone as have their ridges thus placed in the middle are fit to be made into gun flints. In this manner the workman continues to split or chip the mass of flint in various directions, until the defects usually found in the interior render it impossible to make the fracture required, or until the piece is reduced too much to receive the blows by which the flint is divided.

Five different parts may be distinguished in a gun flint. 1. The sloping facet, or level part which is impelled against the hammer of the lock of the gun. Its width should be from two to three-twelfths of an inch; if it were broader it would be too liable to break: and if more obtuse the scintillation would be less brisk. 2. The sides or lateral ridges, which are always rather irregular. 3. The back, or the part opposite the tapering edge: this is the thickest part of the flint. 4. The under surface, which is uninterrupted and rather convex. And, 5. the upper facet, or small square facet, between the tapering edge and the back, which receives the upper claw of the cock; it is slightly concave. In order to fashion the flint, those scales are selected that have at least one of the above mentioned longitudinal ridges. The workman fixes on one of the two tapering borders, to form the striking edge; after which the two sides of the stone that are to form the lateral edges, as well as the part which is to form the back, are successively placed on the edge of the chisel, in such a manner that the convex surface of the flint which rests on the forefinger of his left hand, is turned towards that tool. He then with the round hammer, gives some slight strokes to the flint, just opposite the edge of the chisel underneath; by which means the flint breaks exactly along the edge of the chisel.

The last operation is to trim, or give the flint a smooth and equal edge. This is done by turning the stone, and placing the edge of its tapering end on the chisel, in which situation it is completed by five or six slight strokes with the wheel hammer, and becomes of the figure represented at *l* and *m*.

The whole operation of making a gun flint is performed in less than one minute. A good workman is able to manufacture a thousand good chips or scales

Fig.



a day, if the flint nodules be of good quality; and in the same manner he can fashion five hundred gun flints in a day, so that in the space of three days he is able to cleave and finish a thousand gun flints without farther assistance.

When the gun flints are completed, they are sorted into two classes, fine and common flints, and according to their application, into flints for pistols, fowling pieces, and muskets. A good flint will give fifty strokes without being unfit for service.

## *Gems altered by Art.*

Lapidaries are accustomed to improve and change the colours of gems by exposing them to heat, and other chemical agents.

In India yellow carnelians are put into an earthen pot, covered with dry goats' dung, and heated for twelve hours, by which they are changed into a fine red. Instead of goats' dung, sand may by used.

Black rock crystal is rendered colourless by heat, if continued for some hours; otherwise it will be only yellow.

Bucquet made a chemical distinction between rock crystal and quartz; the latter, cracking by heat, probably on account of containing water.

The amethyst by a moderate heat becomes colourless; but if the heat is violent, white and shotten like an opal, it is more liable to crack in the fire than rock crystal.

Beryl is changed by a moderate heat to a light blue; if the heat is greater it becomes like mother of pearl.

The emerald acquires the same pearly lustre by heat.

The colour of the chrysoberyl is not altered by heat.

Blue fluor spar is changed to red, and if the heat is strong, is often rendered colourless.

Agates absorb oil, either by being immersed or boiled in it for a sufficient time, or even during the process of cutting them; and on boiling them in oil of vitriol, the parts which have absorbed the oil are rendered black, while the other parts retain their natural colour, or even become whiter than before.

Agates and carnelians having carbonate of soda applied to them, and then exposed to the heat of a furnace under a muffle, an opake white enamel is thus made to cover the stone, which cannot easily be distinguished from a natural white flake. By this means are produced the carnelian beads brought from India, which are ornamented with a net work of a white colour, penetrating to a small depth, and equally hard as the stone itself.

## *Glass.*

Glass is one of the earliest and most valuable productions of chemical art. The mummies in the Catacombs near Memphis, are ornamented with glass beads, as also, those of the Thebaid, so that it was known 1600 years before the commencement of our era; yet it is not mentioned by any of the writers in the

compilation of the ancient Jewish writings called the Old Testament. Among the Greek writers Aristotle is the first person who mentions it, and it is not mentioned by any of the writers collected in the New Testament, except in the epistles of Paul and Peter, and in the work called the Revelation. Glass was little known even in Rome before 536 U. C. (or 213 A. C.) nor used for windows before Nero; Martial mentions it as applied to the green house or hot house. It was introduced into England about 670 by Theodorus, archbishop of Canterbury. By glass we enjoy the sight of surrounding objects without being exposed to the inclemency of the weather; and are enabled to observe the action of heat and mixture in transparent bodies, far better than we could in opake vessels made of pottery ware.

The manufactory of glass is mostly carried on by large capitalists, who use glass houses which are usually conical domes from fifty to eighty feet in diameter at bottom, and sixty to one hundred feet high, in order to ensure a good draught. The principal furnace is erected in the centre, over a large vault extending across the whole area, and allowing a passage to workmen with barrows to extract the ashes. The furnace in the British Islands is built with fire-bricks, set with Stourbridge clay; but on the continent it is more commonly made of raw clay rammed together, and then baked into a solid mass by a fire made in it and slowly and gradually increased. Holes are left on the sides to introduce the fuel and pots, and those for the latter purpose are partly bricked up, leaving only a hole for filling or emptying the pots. The crucibles or pots in which the glass, or metal as the workmen call it, is melted, are made of an infusible clay; in these islands that of Stourbridge is chosen, either kneaded by itself, or more generally with a mixture of a small proportion not exceeding a fourth part of the upper part of old pots reduced to powder. The pots are sometimes made in moulds by a screw press, but the most usual method is that of the French portable furnace makers, namely, to knead the clay until it is rendered as tough as is possible, then make it into rolls, and press these together with the hands and a mallet.

The crucibles or pots for bottle and window glass, are generally forty inches deep, as many wide at top, and thirty at bottom; they are not covered, and are from three to four inches thick. The pots for flint glass are of various sizes and shapes, and are covered with a spherical dome. They are from two to three inches thick, and have a semicircular opening on the side towards the top, to which is fitted a stopper.

The changing of the pots in a furnace is the most severe labour in chemistry. Being first thoroughly dried, they are

Fig . 120 .

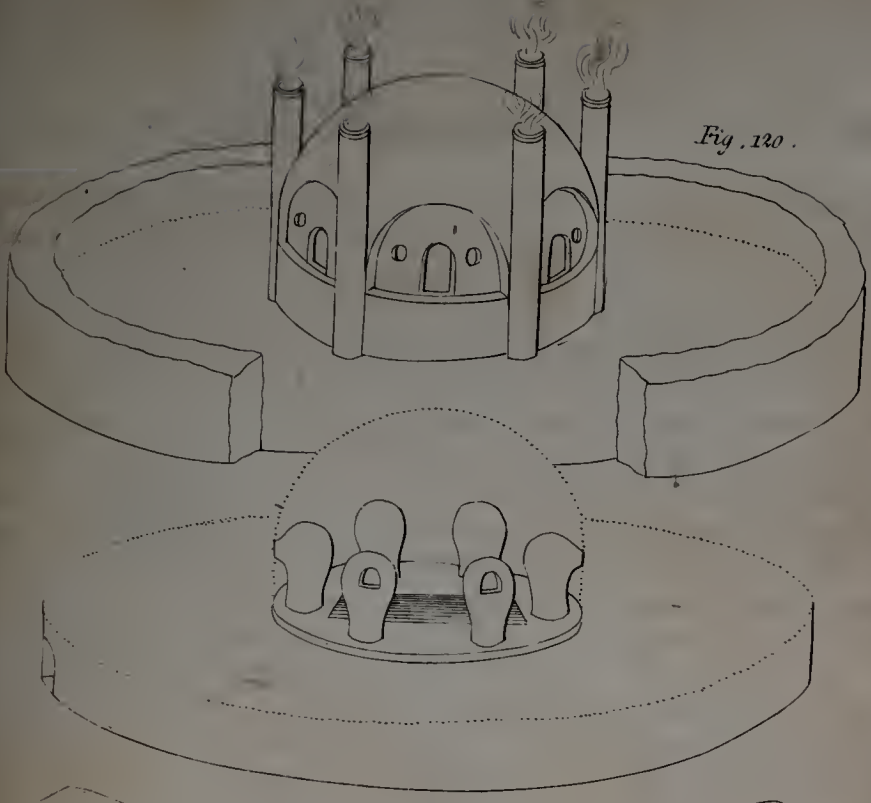


Fig . 121 .

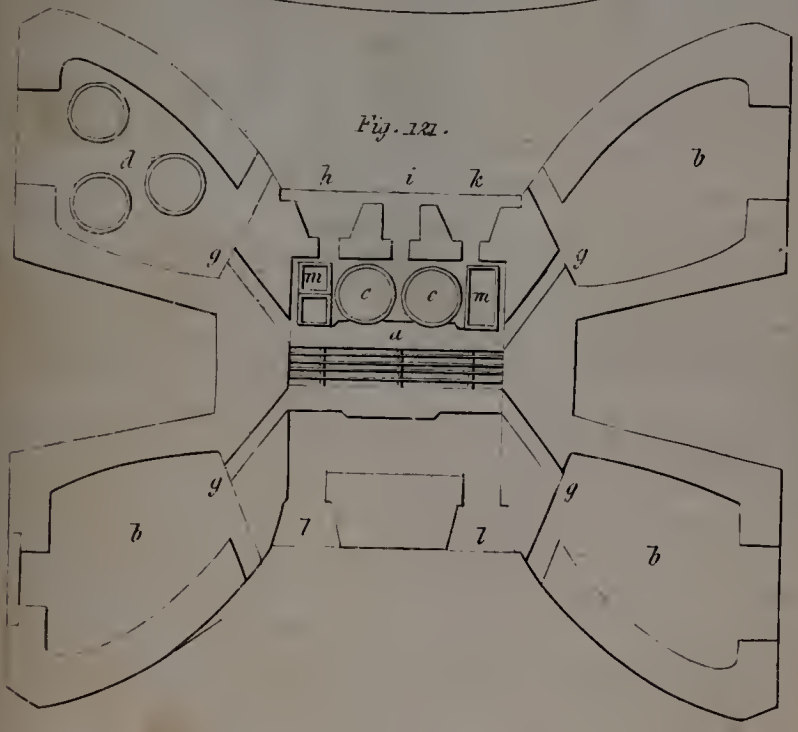
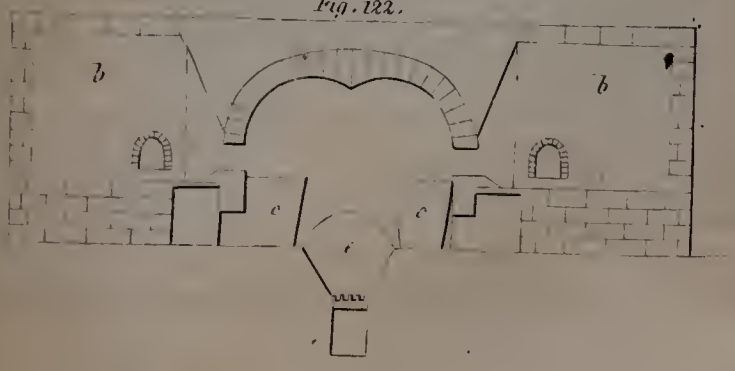



Fig . 122 .



heated in a furnace built expressly for this purpose, by a fire increased gradually for four or five days, until they are brought to a white heat. When ready, the opening in the glass furnace has the bricks with which it is partly closed removed, and the old pot pulled out with iron hooks. An operator then puts on a hood, jacket, and pantaloons, formed of raw hides, thoroughly soaked in water, so as to sheathe himself entirely, except the parts opposite the eyes, which are defended by very thick plates of glass, and the pot being taken from the annealing arch, is instantly put by him into its place in the furnace by his hands only, without extinguishing or even diminishing the fire; after which the opening is again bricked up, except the hole left for working the glass.

### *Bottle Glass.*

This is the coarsest kind of glass; in some countries it is made from various kinds of stones, as basalt, or lava; it may also be made from common sand or lime, with a little clay and common salt. But in England it is made from coarse sand and the waste earth of kelp from which soap boilers have washed out the alkali.

The bottle glass furnace is represented in Fig. 119, and is generally an oblong square chamber, covered over with a higher or lower arch, according to the fancy of the manufacturer. The grate is in the middle, and on each of the long sides is a bank a foot high and three wide, upon each of which a couple of pots are placed. The fire doors are at the narrow ends, and are closed with sliders, *a*. The openings at which the pots are put in are bricked up, except a square working hole about a foot each way.

A calcining furnace, *b*, is built at each angle, with two holes of a foot square, one to allow the flame to enter the furnace, the other to manage the materials in them.

Two of these calcining furnaces are called the coarse arches, and are used for calcining the soap makers' waste, where it is kept red hot during the 24 or 30 hours that the melting journey, or time of melting the glass, usually lasts.

The ashes, as the waste is called after this operation, are then taken out and mixed with common winter sand, according to the strength of the ashes, the most general proportion being three bushels of ashes to one of sand. The mixture being effected, is put into the other two calcining furnaces called the fine arches, and calcined during the ten or twelve hours that the working journey, or time of blowing the bottles, lasts. When the working journey is over, the pots are re-filled with the red hot materials out of the fine arch, which takes about six hours to melt; more materials are then added, and this second filling requires about four hours more firing before it is melted.

The melting being accomplished, the heat is kept up to fine the glass from twelve to eighteen hours; when the doors of the ash vault are shut, the glass as it cools throws up its impurities, which are skimmed off. The furnace is then filled with coal, so as to retain a working heat for four or five hours, during which the bottles are blown; a farther addition of coal is then

made, to keep it in a working heat till the whole of the glass is blown into bottles; six persons are employed in the blowing of each bottle.

The bottle glass house generally contains, besides the proper glass furnace, six other furnaces, or arches, for annealing the bottles by cooling them gradually; and two furnaces for annealing pots previous to setting them in the furnace.

### *Best Window Glass.*

This is generally made from fine sand, with about twice its measure of the best kelp. That of the Orkney Islands is preferred to the Western Island kelp; but Bowles, a celebrated manufacturer of this glass, used Spanish barilla, as being still purer.

The calcining furnace, in these houses, is entirely separate from the fonding or melting furnace. It is about six feet square, having an arch thrown over it about two feet high. The bottom of the bank on which the materials are placed, about six Cwt. at a time, is about three feet and a half from the ground. To prevent the alkali from being lost, an iron plate is sometimes built in under the bottom of this bank, but others prefer to form air flues, to keep the bottom of the chamber so cool as to fix the alkali, and thus stop its passage.

The materials are calcined in this furnace at first with a gentle heat for three hours, keeping it continually stirred; the heat is then raised, so as to nearly melt it, and this heat is kept up for about two hours; at the end of which time the frit is drawn out of the furnace, upon an iron plate, and before it cools divided into large cakes, which are piled and kept for at least six months before they are melted, or longer if the manufacturer is possessed of sufficient capital.

The pots in the fonding furnace are filled with this frit, and upon it is piled about one-eighth its weight of broken glass. In ten or twelve hours' firing the frit is melted, and a fresh parcel is then added, which melts, and the whole is left to settle, until the glass or metal becomes fine, and fit for blowing. This fonding requires thirty or thirty-six hours' intense heat; the heat is then diminished gradually in two hours to a working heat, during which the glass settles.

Fig. 120, represents the furnace used for melting the best window glass. It is usually of such size as to hold four or six pots, capable of containing sixteen or even twenty Cwt. of glass. Besides this furnace and the calcining arch, the house contains a flashing furnace, and bottoming hole for working the glass, along with several annealing arches, as well for the glass as for the pots, to supply the place of those that become cracked.

Crown glass is usually blown first into a globe, and then the globe is heated by rapidly twirling it opposite to the working hole, which softens the part of the globe opposite the neck,

*Fig. 119*

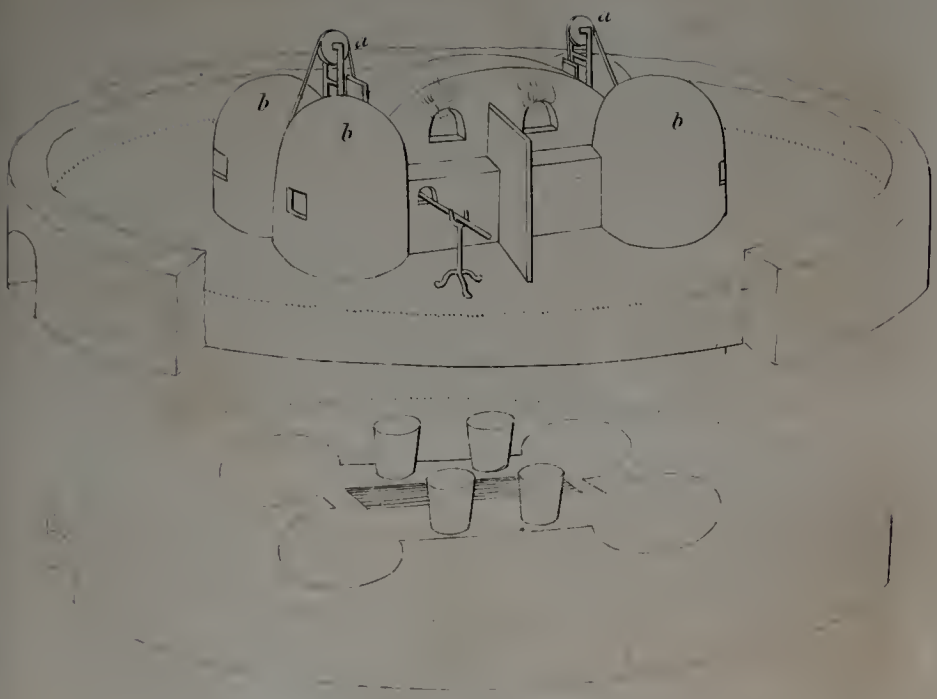



*Fig. 120*

and thus by the centrifugal force of its particles, the globe is expanded into a slightly convex plate; being suffered to cool a little, the glass is separated by the application of a cold iron from the blowing tube, and taken up on another iron, fixed by melted glass to the centre of the part opposite the neck; it is then softened by heat, and being rapidly twirled, the neck opens, and at a certain period the now conical frustrum suddenly changes to a flat circular plate, with a knob in the centre.

The same glass is sometimes made into window plate, German plate, or table glass. In this case the glass is blown into a large cylinder, which being cut, while soft, longitudinally by a pair of shears over a copper table, it sinks down into a flat table, and is carried to the annealing arch.

### *Flint Glass.*

This is so called, because it was formerly made of calcined flints; but at present a fine quartzose sand, found at Lynn, is employed as the basis; this sand is well washed, calcined, and sifted, in a sieve of fifty meshes to the inch, running measure. The flux is composed partly of red lead, or which is generally preferred, of litharge, and of purified pearl-ash; the proportions being 100 of sand, 60 of red lead or litharge, and 30 of purified pearl-ash. Soda makes a harder glass than pearl-ash. but it communicates a greenish blue tinge, and therefore will not do for the generality of articles, for which flint glass is used, as they require the utmost clearness and freedom from colour. Saltpetre is added in small quantities, to secure the oxidation of the lead; white arsenic is also added, with the same intention, but care must be taken that too large a quantity is not added, as this would produce a white cloudiness in the glass. Another oxidizing ingredient scarcely ever omitted, is black manganese, to change the greenish yellow, or olive tinge, given by the iron contained in the sand into a purple tinge, but it greatly injures the transparency. Hence a necessity for employing the purest sand, oxide of lead and pearl-ash, that can be procured, for manufacturing flint glass.

Fig. 121, represents a flint glass furnace, which is constructed so as to yield a greater heat than the preceding furnaces, in order that the glass may run thin, and thus the impurities, or sandiver, rise the easier through the liquid mass.

The pots used in fouding flint glass, are in English glass houses always covered, on account of coal being used for fuel. The materials are taken from the mixing house to the glass house, and about a dozen shovelfulls are put at once into each pot; in two or three hours this is melted, and more is added, till the pot is full. The mouth of the pot is then closed up, by putting soft clay round the stopper, except a small opening, through which the sandiver escapes, in consequence of the melted glass being hotter at the side next the

fire than next the mouth. As soon as the glass is fine, and free from all air bubbles, the workmen begin to blow it into wares.

The manufacture of flint glass for optical purposes, particularly for telescopes, requires extraordinary care, as the veins which usually exist in flint glass, on account of the great difference in specific gravity between its ingredients, are very prejudicial to the accuracy of the image. Dollond, the optician, was once lucky enough to find a large mass of flint glass free from veins, but no method is known of securing this valuable quality in a batch of glass.

M. Cazalet, of Bordeaux, has, indeed, proposed the following materials, as capable of forming a glass free from veins, and other imperfections: one hundred pounds of red lead, sixty of white sand, fifty of refined saltpetre, and one of fine white chalk. And an ingenious Swiss artist is said to have discovered a successful method of constantly forming this desirable article.

## *Plate Glass.*

This, though not the finest glass, is remarkable for the mode of its being rendered fit for use, which is not by blowing, as in the other kinds, but by casting in sheets like lead; hence it must not be liable to fix too soon, as this would hinder it from being spread on the moulding table.

The sand used for plate glass is usually fluxed with purified barilla, with some addition of pearl-ash; borax, and a small proportion of quicklime, are also used for facilitating the melting, and black manganese to prevent the yellow or red tinge arising from the accidental presence of oxide of iron, and to give the glass a dark tinge, which increases its reflective power, as it is mostly used for looking-glasses. Each manufacturer has his own proportions of materials. Parkes mentioned one who used 430 parts of very white sand, 265 of dry carbonate of soda, procured by acting upon common salt by pearl-ash, forty of quicklime, and fifteen of refined saltpetre. The materials are mixed together, and calcined in the chamber of a reverberatory furnace for five or six hours.

Fig. 122, represents a plan, and 123, a section of the fonding furnace of a plate glass house. The proper furnace, *a*, which contains two pots on each side, is surrounded by four chambers, *b*, *d*, which are heated by the flame passing through the bridges, *g*. Three of these chambers, *b*, are used for burning the pots and cisterns; the fourth chamber, *d*, fritting the materials before they are put into the melting pots.

The fire is made in the grate, at *e*, fig. 123, which is included between the two sloping sides of the banks on which the pots, *c*, and cisterns, *m*, are placed. The fuel is supplied through the arches, *e*, fig. 123, which are of sufficient

size to introduce new pots, but are then bricked up, except a small hole at bottom. On each side of the furnace are three working holes, *h*, *i*, to admit the iron ladles by which the glass is put into the pots, or when melted, laded into the cisterns. Openings, *l*, are made on a lower level, by which the cisterns may be put in, or drawn out of the furnace; and in this level is placed an iron floor, as shown by the dotted lines, to receive the cisterns.

To bake the pots or cisterns gradually, the flues, *g*, leading to the chambers, *b*, are provided with dampers; these being shut, the pots or cisterns are placed in the chamber; after which, the dampers are gradually opened to admit the heat gradually, and avoid the danger of cracking the pots or cisterns.

The frit taken from the reverberatory furnace is mixed with a quarter its weight of broken plate glass, previously reduced to powder by heating it in the chamber, and throwing it while hot into cold water. After which, it is mixed with the frit, and other materials, and the composition is again calcined for some hours in the same chamber, until they begin to melt.

This thick paste is laded out into the pots, where, by thirty-six or forty-eight hours' firing, they are converted into glass. Some of this glass is then taken out, and if thick, or imperfectly melted, some borax is usually added, and if too coloured, black manganese, white arsenic, or a mixture of these oxides is wrapped in brown paper, and thrust down to the bottom of the pot.

When the glass is fine, it is laded out of the pots into the cisterns, where it remains five or six hours; and then the cistern being withdrawn, its contents are poured out upon a thick copper table, brought for that purpose to the opening, *l*, by which the cistern is withdrawn. To regulate the breadth and thickness of the plate, two iron ledges, of the required thickness, are laid upon the table, and a copper roller, weighing about five Cwt., pushes the liquid glass before it. The plate is then shoved, as quickly as possible, into an annealing furnace, where it remains for fourteen days, cooling gradually.

The plates thus made, are then ground level by sand, and polished by emery of different finenesses, by Tripoli, and putty powder.

The above quantity of materials produce about 700 parts of plate glass.

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Glauber's salt may be employed in glass making without any addition of potash or soda, and it makes beautiful and white glass. It does not indeed vitrify quartz perfectly, even in the strongest fire. The fusion is more complete if lime is added, but even this requires a deal of time and fuel. By decomposing the sulphuric acid the vitrification is quite perfect. For

this purpose the best medium is charcoal, or for flint glass, metallic lead.

This decomposition may be effected during the fusion, or previous to it, but there must be observed:—The property charcoal has of colouring glass, even when in very small quantity, in which it is not exceeded by any of the metallic oxides. A preference is to be given to lime reduced to powder, dissolved in water and heated again, before lime slaked in the air.

The great effervescence of the glass, so that it must be added in smaller portions than if potash was employed. Sulphuret of soda may be more useful in glass making than the sulphate. The pots must be of good clay, as the sulphate of soda acts violently upon them; the best proportion for drinking glasses is 100 parts of sand, 50 of dry Glauber's salt, from 17 to 20 of lime, and 4 of charcoal. Sulphate of soda dissolves more silica than potash. Sandiver is decomposed by adding charcoal. Glass made with felspar containing potash, generally abounds with blebs, yet it is possible to make good glass with it.

If a small quantity, even a pint of water were to be thrown into a crucible of glass in a melted or rather a melting state, while the scum or sandiver is upon its surface, the water would be converted instantly into steam, so that an explosion would take place; and if the quantity of water were more considerable, the furnace would probably be blown down. Indeed, the taking off the sandiver in iron ladles, and plunging them in water, has been used to salute visiters of importance, with explosions like a salute of ordnance. But when the sandiver has been scummed off, and the glass in quiet fusion, if water is thrown on it, the globules dance upon the surface of the melted glass for a considerable time, like so many globules of quicksilver upon a drum head, while the drummer is beating it; and on this account, when melted glass is flung into water to calcine it, care must be taken to skim it well, before it is ladled out.

In the manufacture of black bottles it frequently happens that while the workmen are employed in moulding and blowing the bottles, that the glass, or metal as it is called, becomes too cold to work, so that they find it necessary to desire the firemen to throw in coal and increase the heat.

This, however carefully it may be done, will sometimes produce so much dust that the surface of the glass becomes covered with coal dust. When this accident occurs, it occasions such a motion within the melting pot, that the glass appears as if it were actually boiling; and if the metal was used in this state every bottle would be speckled throughout and full of air bubbles.

Whenever this circumstance takes place, the workmen throw a little water into each of the melting pots. This water has the effect not only of stilling the boiling of the glass immediately, but it also renders the melted metal as smooth and pure as before.

### ARTIFICIAL GEMS.

A number of authors have given receipts for making those coloured glasses which are employed in cheap jewellery as substitutes for the more valuable gems.

Amongst these authors M. Fontanieu seems to be the person who has given the simplest, and therefore probably the best formulæ for composing of these coloured glasses.

For M. Fontanieu's colourless base, crystal or pebbles being pounded are put into a crucible and heated red hot; the contents are emptied into cold water. The water is then decanted, and the mass being dried and pounded, is sifted through a sieve of the finest silk, after which the powder is digested in muriatic acid, and being frequently washed, is again dried and sifted for use. From the earth thus obtained, M. Fontaineu formed six different bases, of which the fifth seems to be that which, in respect of quality, is preferred by himself.

The first base is formed by twenty ounces of litharge, twelve ounces of prepared rock crystal or flint, four ounces of arsenic, which being well pulverized and mixed, are melted in a Hessian crucible, and poured into cold water. The mass is melted again the second and a third time, always in a new crucible, and after each melting poured into cold water as at first, taking care to separate any lead that may be revived.

The second is obtained from a mixture of twenty ounces of white lead, eight ounces of prepared flint, four ounces of purified pearl-ash, and two ounces of calcined borax, all melted in a Hessian crucible and poured into cold water. The melting must be repeated, and the mass washed a second and third time with the same precautions as before.

A compound of sixteen ounces of red lead, eight ounces of crystal, four ounces of saltpetre, and four ounces of purified pearl-ash, constitutes the third base, being treated as in the preceding examples.

The fourth is formed by eight ounces of rock crystal, twenty-four ounces of calcined borax, eight ounces of purified pearl-ash, mixed and melted together, and poured into warm water. The mass being dried, an equal quantity of red lead is to be added, and the whole repeatedly melted and washed as before.

The fifth, or Mayence base, is thus made: Eight ounces of rock crystal, or flint pulverized, is baked along with twenty-

four ounces of purified pearl-ash, and the mixture left to cool. The frit is afterwards poured into hot water to moisten it, and the nitric acid added until it no longer effervesces. The water being decanted, the frit must be washed in warm water until it ceases to have any taste, and the frit being then dried and mixed with twelve ounces of fine white lead, the mixture is to be well levigated with a little distilled water. An ounce of calcined borax is now to be added to twelve ounces of this powder when dried, and the whole well mixed, then melted and poured into cold water, in the same manner. After repeating these fusions five drams of nitre are to be added and the whole melted. A mass of crystal having a beautiful lustre will be found in the crucible.

Lastly, a very fine white crystal glass may be obtained from eight ounces of white lead, two ounces of borax finely powdered, half a grain of manganesé, and three ounces of rock crystal, treated as the rest.

The colour of artificial gems is obtained from metallic oxides. The diamond being colourless is imitated by the Mayence base, or strass as it is called, and M. Fontanieu has given numerous receipts for making all other fictitious gems, of which the following are examples.

Oriental topaz is imitated by adding 360 grains of antimony to colour 13,834 of the first or third base. Amethyst by taking 13,834 grains of the Mayence base, to which are to be added 288 of manganese, prepared by being exposed to a red heat and quenched in distilled vinegar, then dried, powdered, and passed through a silk sieve, and also four grains of the purple precipitate of Cassius.

The beryl is imitated by 96 grains of antimony and four grains of oxide of cobalt, added to 13,834 grains of the third base.

The yellow diamond, by melting 24 grains of muriate of silver, or ten grains of glass of antimony with 576 grains of the fourth base. The sapphire by 13,824 grains of the fifth base and 190 grains of oxide of cobalt. The emerald by 8640 grains of any base, with 72 of mountain blue, and 6 of glass of antimony. The common opal by 576 grains of the third base, 10 of muriate of silver, 2 of calcined loadstone and 26 of lime.

M. Donault Wieland has given some other formulæ; and observes that Hessian crucibles are far better than those of porcelain for melting the compositions, and that the glass should be kept for 24 hours in a uniform heat since the beauty depends greatly upon this long continued and tranquil fusion.

Colourless glass or paste:

| | *No.* 1. | *No.* 2. | *No.* 3. | *No.* 4. |
|---|---|---|---|---|
| Rock crystal calcined, | 4056 | —— | 3456 | 3600 |
| Sand, | —— | 3600 | —— | —— |
| Red lead, | 6300 | —— | 5328 | —— |
| White lead, | —— | 8508 | —— | 8508 |
| Purified pearl-ash, | 2154 | 1260 | 1944 | 1260 |
| Borax, | 276 | 360 | 216 | 360 |
| White arsenic, | 12 | 12 | 6 | —— |

For artificial topaz he takes 1008 grains of colourless paste, 43 of glass of antimony, and 1 of Cassius' purple precipitate; or 3456 grains of paste, and 36 of red oxide of iron made by fire. For ruby, 2880 grains of paste, and 72 of black manganese. For emerald, 4608 grains of paste, 42 of green oxide of copper, and 2 of oxide of chlorine. For sapphire, 4608 grains of paste, 68 of oxide of cobalt, and 1 of Cassius' precipitate. For beryl, 3456 of paste, 24 of glass of antimony, and one and a half of oxide of cobalt. For the Syrian garnet or carbuncle, 512 of paste, 256 of glass of antimony, 2 each of Cassius' precipitate and of black manganese.

## *Stained Glass.*

This art has been repeatedly described as being no longer known; but this is not the case, except in respect to some particular colours which are found in church windows.

M. Brogniart, director of the porcelain manufactory at Sevres, has made many experiments on painting on glass, or staining it, as the art is more usually called.

The glass used for staining should not have any oxide of lead in its composition, and the colours are the same as those used in enamelling.

A very beautiful violet, but liable to turn blue, is made from a flux composed of borax and flint glass, coloured with one-sixth part of the purple precipitate of Cassius.

A fine red is made from red oxide of iron, prepared by nitric acid and fire, mixed with a flux of borax, and a small proportion of red lead.

A yellow, equal in beauty to that produced by the ancients, may be made from muriate of silver, oxide of zinc, white clay, and the yellow oxide of iron mixed together without any flux. A powder remains on the surface after the glass has been baked, but this is easily cleaned off.

Blue is produced by oxide of cobalt, with a flux composed of fine sand, purified pearl-ash, and red lead.

Black is produced by mixing the composition for blue, with the oxides of manganese and iron.

To stain glass green, it must be painted blue on one side, and yellow on the other.

The colours ground with water being laid upon the glass, must be exposed to heat under a muffle, so as to be heated equally until the colour is melted upon the surface. To prevent the panes of glass from bending, they are placed upon a bed of bone ashes, or of quicklime, or, as M. Brogniart ordered his painters to proceed, upon flat plates of biscuit, that is, unglazed porcelain. A bed of gypsum has been recommended, but the sulphuric acid exhaling from it is apt to render the glass opake, white, and cracked.

### *Glass Beads.*

Drs. Hoppe and Hornschuch in the Journal of their tour to the coast of the Adriatic sea, give the following account of the far famed manufactory of glass beads, carried on at Murano, a place adjoining Venice.

The furnace and the white glass are similar to what is seen in the common glass houses; but they mix with this white glass peculiar colouring substances of which they make a great secret. The coloured glass being reduced to a melted state, a certain quantity is taken up by the blow pipe used by the workmen, and is blown hollow; a second workman lays hold of the other end of the glass ball, and both the workmen run with great expedition two opposite ways, and thus draw out the glass into pipes, the thickness of which differ in proportion to the distance. A long walk of 150 feet, like a rope walk, is attached for this purpose to the glass house.

As soon as the pipes are cooled they are divided into pieces, all of the same length, sorted, packed in chests, and sent to the bead manufactory in Venice itself. Striped pipes are made by taking two lumps of glass from pots of different coloured glass, twisting them together, and then drawing out the whole to the proper length. They also manufacture pipes three feet long and of the thickness of a finger; these have a ball blown at one end, and are used to tie up plants in flower pots.

When the pipes arrive at the bead manufactory in Venice, a person picks out pipes of the same thickness, which he cuts into small pieces of the size he thinks necessary. For this purpose a sharp iron in the shape of a broad chisel is fixed in a wooden block; the workman places the pipes of glass on the edge of this tool, and with a chisel-like tool in his right hand, he cuts, or rather chips the pipes into the sizes that are proper for the various sized beads.

These fragments of the pipes are then put into a mixture of sand and wood ashes and stirred until the hollow of all the pipes

are filled, in order to prevent their sides from running together by the heat of the fire. They are then placed in a vessel with a long handle, more sand and wood ashes are added, the whole placed over a charcoal fire, and stirred continually with a spatula resembling a hatchet with a round end; by this simple means they acquire a globular figure. The sand and wood ashes are then separated by sifting, and the beads themselves sorted by other sieves into different sizes. Each size are then strung upon threads, made up into bundles, and packed ready for exportation.

The extent to which this manufactory is carried is astonishing; many hundred weight stand ready filled in casks, to be sent to all parts of the world, but particularly to Spain and the coast of Africa.

### *Moulded Gems.*

The extreme beauty of many engraved gems and their high price render the taking of copies from them in coloured glass a very desirable art. M. Homberg has given the following minute directions for this purpose.

A quantity of soft, smooth, red Tripoli is pounded in an iron mortar, sifted through a fine silk sieve, and set aside for use. Another species, called yellow or Venetian Tripoli, which has a natural kind of unctuosity, is then scraped with a knife, and bruised in a glass mortar with a glass pestle, until reduced to a very fine powder: the finer it is the more favourable for the impression. The red Tripoli is now to be mixed to the consistence of paste with water, and when moulded between the fingers it is put into a small flat crucible, scarcely exceeding half an inch in depth, and little more in breadth at the surface than the size of the gem whose impression is to be taken. The crucible is then to be filled with the paste slightly pressed down into it, and the dry yellow Tripoli strewed over its surface. Upon this bed the stone which is to give the impression must be laid, and pressed down so much on the paste as to give it a strong, clean, and perfect impression; and the Tripoli is to be collected and applied nicely to the edges with the finger or an ivory knife. After the stone has lain a few seconds to allow the humidity of the red Tripoli paste to moisten the dry powder of the yellow Tripoli scattered over it, the operator must raise it carefully by a needle fixed in a wooden handle, and the crucible being inverted, it will fall out, while the impression remains on the Tripoli still adhering to the crucible. The stone must now be examined to ascertain whether any of the paste has come off along with it; as in that case there would be a corresponding defect in the impression, and the moulding must be repeated. Having allowed the crucible and paste to dry, the artist selects a piece of coloured

glass of the suitable size to be laid over the mould, but in such a manner as not to touch the impression, which would thus be obliterated or injured, and the crucible being gradually brought nearer the furnace is to be heated until it can no longer be touched by the hands, when it must be placed in the furnace under a muffle, surrounded with charcoal. When the gem begins to appear bright, it is the sign of being ready to receive the impression. The crucible must now be taken from the fire and the hot gem pressed down with an iron implement, to make it receive the impression from the mould below it; after which the crucible is to be set by the sides of the furnace to cool gradually without breaking. When cold the gem may be removed, and its edges nipped or grated round the pincers to prevent it from cracking, which sometimes happens.

Red Tripoli is used for the paste only from economy, as it is the yellow species alone which is adapted for the purpose. Casts of plaster of Paris made into small cakes half an inch thick, may in some cases be substituted for Tripoli moulds, and being put into a furnace without a crucible and heated, the coloured glass may be pressed down upon it to take the impression.

Another species of these moulded gems is that which was adopted by Mr. Tassie. In these copies the original transparent or semi-transparent gem is not attempted to be imitated, but the copy is taken in a beautiful white enamel, sufficiently hard to strike fire with steel.

### *Reaumur's Porcelain.*

It had been frequently observed that during the annealing of green glass, some parts of it became white and opaque; M. Reaumur made experiments on this apparent devitrification of glass, and found that it was owing to the alkali flying off by the too long continuance of the heat, or its excessive power, and that the opaque changed glass had acquired the quality of bearing sudden transitions of heat and cold as well as the best porcelain.

For the purpose of making vessels of this kind, common bottle glass is chosen, and blown into the proper form. The vessel is then to be filled to the top with a mixture of white sand and gypsum, and then set in a large crucible upon a quantity of the same mixture, with which the glass vessels must also be surrounded and covered over, and the whole pressed down rather hard. The crucible is then to be covered with a lid, the junctures well luted, and put into a potter's kiln, where it remains during the whole time that the pottery is baking, after which the glass vessel will be found changed into a milk-white porcelain.

The glass, on fracture, appears fibrous, as if it were composed

merely of silken threads, laid by the side of each other; it has also quite lost the smooth and shining appearance of glass, is very hard, and emits sparks of fire when struck with steel, though not so briskly as real porcelain. Lewis observed that the above-mentioned materials have not exclusively the effect upon glass, but that powdered charcoal, soot, tobacco-pipe clay, or bone ashes, produce the same change. It is remarkable that the surrounding sand becomes in some measure agglutinated by this process, which if continued for a sufficient length of time, entirely destroys the texture of the glass, and renders it incoherent, and reducible with great ease to a kind of sand.

### *Ultramarine Blue.*

This precious colour is obtained from the stone called lapis lazuli, by heating it, reducing it to powder, by throwing it while hot into water, then washing away the lighter particles by water, and grinding it very fine. The ground stone is then incorporated into a melted mass formed of equal parts of rosin, wax, and linseed oil. The mass is then kneaded with the hands in warm water, the first portion of which is usually rendered dirty; but as soon as a blue colour appears, the water is changed, and then the ultramarine blue is collected, being washed out of the kneaded mass.

As the value of the ultramarine blue is very great, the purchaser is liable to have cheaper substitutes imposed upon him: the genuine blue suffers no change of colour by being heated; nor does it effervesce with oil of vitriol, but in this, or any other strong acid, it loses its colour, and leaves a dirty white sediment, the solution is colourless, and yields a very slight white precipitate with ammonia water: if boiled in carbonate of potasse water, the intensity and brilliancy of its colour is increased.

Ultramarine blue is used to paint the sky as it appears in warm countries; but as this colour does not change by age, like the others used in the same picture, the harmony of the colouring is gradually lost, and the sky becomes too brilliant in comparison with the remainder of the picture.

### *Smalt, or Powder Blue.*

This is a blue glass colour, made by melting three parts of fine white sand, or calcined flints, with two of purified pearlash, and one of cobalt ore previously calcined, and lading it out of the pots into a vessel of cold water; after which the dark blue glass or zaffre is ground, washed over and distributed into different shades of colours, which shades are occasioned by the different qualities of the ore, and the coarser and finer grinding of the powder. It is usual to distinguish these blue glass colours

by certain combinations of letters, C, signifying colour; E, eschel, that is to say, ash; F, fine; F F, finer; F F F, finest; H, high; M, middling; and O, ordinary.

Smalt is used in painting as a substitute for ultramarine blue; and to give linen a bluish tinge.

### *Naples Yellow.*

There are two different processes for making this glass colour that have been published.

That of the Abbate Passeri is by calcining one pound of common antimony, and one and a half of lead, with an ounce each of alum and of common salt.

M. Fougeroux calcines twelve ounces of white lead with two of peroxide of antimony, one of sal ammoniac, and half an ounce of calcined alum, for three hours, in a covered crucible, till it becomes barely red hot.

### *Enamel Colours.*

Enamel colours are of two kinds, transparent and opaque; the latter quality being caused by adding oxide of tin to the transparent basis of the other enamels, which differs only from coloured glass, by its greater fusibility and softness.

The best opaque white enamel was brought from Venice, in two-pound cakes, marked Bertolini; but this manufacturer being now dead, the article is no longer to be procured. An enamel superior in whiteness, but inferior in its power of retaining a transparent glaze laid over it, has been prepared in London. The cause of this difference is supposed to arise from the Venetian maker having used a pure oxide of Malacca tin; while the others use the common putty powder, thrown out by heat from an alloy of two parts of English tin with one of lead. Upon such slight differences, unnoticed, and indeed laughed at by the philosophical chemists, do the perfection of a manufactured article depend.

Mr. Wynn has lately published the following processes for obtaining enamel colours.

| *Fluxes.* | No. 1. | 2. | 3. | 4. | 5. |
|---|---|---|---|---|---|
| Flint glass | 12 | 10 | 3 | 16 | 6 |
| Red lead | 16 | — | 1 | 19 | 8 |
| Calcined borax | 3 | — | — | — | — |
| Flint powder | 4 | — | — | — | — |
| White arsenic | — | 1 | — | — | — |
| Refined saltpetre | — | 1 | — | — | — |
| Borax, not calcined | — | — | — | 11 | — |
| Flux, No. 2. | — | — | — | — | 4 |

The materials for these fluxes are to be well melted, and then poured out upon a flag-stone wetted with a sponge full of water

or into a large pail of clean water; then dried, and finely powdered in a Wedgewood-ware mortar.

For yellow enamel, mix eight parts of red lead with one each of the peroxides of antimony and tin; heat the mixed powder upon a Dutch tile, under a muffle, till it becomes red hot, then let it cool: by varying the proportion of antimony, different shades of colour may be obtained. To two parts of this calcined powder add three of flux, No. 4, and grind them together in water for use.

Orange-coloured enamel is producible from twelve parts of red lead, four of peroxide of antimony, three of flint powder, and one of calcined green vitriol; mix and calcine them together, without melting: to two parts of the calcined powder is then added five of any flux, and the whole melted.

Dark red enamel is produced from seven parts of green vitriol calcined to a dark red colour, six of the flux, No. 4, and one of colcothar; the two latter being previously melted together, and then the whole ground in water.

Light red enamel is made from six parts of the flux, No. 1, three of white lead, and two of green vitriol calcined to redness.

Brown enamel is produced from thirty-four parts of red lead, sixteen of flint powder, and nine of black manganese.

In respect to other colours, oxide of copper produces a green colour, oxide of cobalt, a blue; oxide of iron a very fine black: the oxide of silver also produces a yellow enamel; and oxide of gold a very beautiful red, which stands the fire very well, which is not the case with the red from iron.

Enamel painting is done upon plates of gold, or of copper, whose spring is got rid of by gently hammering the springing parts upon a marble slab with a wooden hammer; annealing them, washing the surface clean with nitric acid. Upon these plates is laid, first on the back with a soft kind of enamel, and then on the front, or face, with hard enamel, ground with water, spread equally on the plate, dried with a fine napkin, and then melted under a muffle. As the flux rises to the surface, by the oxide of tin settling down, the surface is rather more transparent than the bottom, and is used, or ground off by a grit-stone, leaving a uniform rough surface, much whiter than before.

The plate being covered with enamel, and fired, the surface is painted and again fired.

## ALUMINE.

Alumine was originally called *earth of alum*, from the method used to obtain it, by adding alum water to ammonia water,

taking care not to add so much alum water as to saturate the ammonia; a white spongy sediment falls down, which is to be well washed, and then dried.

Like the other earths, alumine is supposed to be the oxide of an unknown metal, called, by anticipation, *aluminum*. Berzelius makes alumine to be Al: and its weight 642,330; but Dr. Thomson, only Al· equal to 2,250.

Alumine is of no use; but it gives their characteristic qualities to clays; although it is not the most weighty ingredient in them; it is also the basis of bricks, tiles, and all pottery wares.

## *Pottery Ware.*

A number of clays are used in the manufacture of this article, which now forms one of the staple manufactures of the kingdom, and gives employment to a vast number of people.

Cornish stone is a species of granite in a state of decomposition, and contains much felspar.

Cornish porcelain clay is this stone more fully decomposed, so that being broken to pieces, and a stream of water directed over them, the clay is washed out, and carried into pits, where it is left to settle and dry; the dried clay is cut into cubic lumps, which are extremely white.

Devonshire black clay is a bituminous porcelain clay, which becomes white on being burned.

Devonshire cracking clay becomes of a beautiful white when burned, but unless the proper proportion of ground flints are mixed with it, the ware will crack in baking.

Dorsetshire brown clay burns very white without cracking, but the baked ware does not readily imbibe the glaze. It is also very difficult to make into a slip that will pass through the silk lawn sieves, unless it has been long exposed to the weather; and the colour of that procured of late years is inferior to that dug formerly, hence many manufacturers will not use it.

Dorsetshire blue clay is very expensive, but forms a very white and solid ware; it requires much ground flint, and a high degree of heat for baking it.

Cheam clay is used for the body of gallipots, and affords a buff-coloured ware.

Bradwall wood clay is a red brick clay.

Hallfield colliery clay is a marle, which burns to a light red ware, of four different shades, according to the degree of heat in which it is burned.

Besides these, and some other clays, the English potters use bone-ash, which gives whiteness to the ware, but renders it liable to crack by sudden changes of temperature.

Ground flints, cawk-stone, called also sulphate of barytes, and ochre obtained by letting the water which flows out of coal pits settle in ponds, are also used in great quantities.

The clays and other materials are made up separately into pulp, or slip, about the consistence of cream, and passed through fine silk lawn sieves; the average weight of the ale pint, or 35 cubic inches ·25 of the pulp of flint is 32 ounces, that of clay 24.

The pulps are then mixed together in certain proportions according to the kind of ware that is to be made, and the mixture reduced with water until a pint weighs a determinate number of ounces. Each manufacturer has his own proportions, which he keeps as secret as possible. The superfluous moisture is evaporated by pumping the pulp to the top of the slip kiln, which is a trough formed of fire bricks, from 30 to 60 feet long, 4 to 6 broad, and about one deep, with flues underneath; during this evaporation the mixture is continually turned over, to dry the whole as uniformly as possible; with the same view the floor of the trough next the fire is made thicker than in the middle, and the middle thicker than the end next the chimney.

The clay is then cut out of the trough and thrown on a heap upon flag-stone, where it is kept as long as the convenience and capital of the manufacturer will allow.

Before the mixed clay can be used in the manufacturing of wares, all the air bubbles must be got rid of by beating it with mallets, cutting it down in pieces, and violently slapping them together by a strong man, by passing through a mill, where the clay is first cut by knives passing through it, and then instantly squeezed together by other knives below. These operations are repeated until the clay on being cut through by a brass wire, presents a perfectly smooth and uniform surface.

The clay is now formed into the proper shape. The first rough shaping is given on a horizontally revolving slab, called the potter's wheel. The clay being dashed upon the centre, is formed by the wetted hand into a pillar, then flattened into a cake, and this repeated until the thrower is satisfied that no air bubbles remain in the mass. He then forms the vessel with his fingers, and moulds it into its required shape, when the vessel is laid by until the clay has acquired a peculiar state, called the green state, in which the remaining operations of fine pottery are best performed.

Common turning is performed on a lathe similar to that of the wood turner: in which the edges of the ware are dressed by means of tools. Engine lathe turning is employed to give some circular species of hard ware a milled edge, as in tea pots. After this, handles or other appendages which have been previously formed by pressing the clay through an opening of the proper form at the bottom of a syringe, are fastened on by means

of slip. The vessel is then trimmed with a knife, and the whole of the joints cleaned off with a moist sponge.

Other articles of pottery are modelled in clay and plaster of Paris moulds made from the model. The clay is first beat with a lump of clay into the required thickness, and then pressed by the hand into the mould. The mould absorbs the moisture of the clay very quickly, and the ware separates easily from the mould, so that the potter may use the same mould five or six times in the course of the day.

Some kinds of ware whose figures are irregular, and whose strength is not important, are formed by casting in plaster of Paris moulds, which are either made of one piece or of several strapped together.

The mixed clay is mixed with water so as to be of the thickness of cream, and poured into the mould, which immediately absorbs the water from the pulp next it, and thus a coating of clay is attached to the mould; the pulp is then poured out, and the clay left for a short time to dry, when fresh pulp of a thicker consistence is poured in, and when a coating is again formed, the pulp is poured off, and the charged mould placed for a short time near the stove until the vessel will part easily from it.

To preserve the ware from the immediate action of the fire, it is enclosed in cases made of marle, old seggars, as the cases are called, ground, and sand; the bottom of each seggar is covered with a layer of fine white sand to prevent the ware from adhering to it.

The pottery ware of Europe is burned twice; first in the biscuit oven, to give consistence to the ware, and enable it to bear the glaze; secondly, in the gloss oven, to melt the glaze; besides these two firings the finer articles undergo another, after being painted upon the glaze or gilt, or black printed; which firing is performed in the enamel kiln.

Fig. 124, represents a section, and 125, a plan of the biscuit and gloss ovens, which differ only in size, the first being the largest, and having four fire rooms round its central chamber. The plan is taken at the height ** in fig. 124, and the section is in the line ** in fig. 125, except that the front view of the opening, *f*, by which the fire is introduced, and the opening, *o*, for admitting air to the fire, are not included in the section, but represented as they appear externally.

The potter's kiln is a cylindrical cavity covered by a flattish dome; this is surrounded by a conical building, serving as a chimney, reaching something higher than the buildings adjacent. The great space between the cylindric part, which is the proper kiln, and the surrounding circular wall, used to be considerably greater than at present, and even now is much too great, as it does not sufficiently obviate an evil which is equally conspicuous in glass houses and in potter's kilns, for the great quantity of cold air which is constantly ascending the cone tends much to check the draught, and by that means renders the fuel less efficacious. Indeed, the cylindric portion or kiln should so nearly

Fig. 124

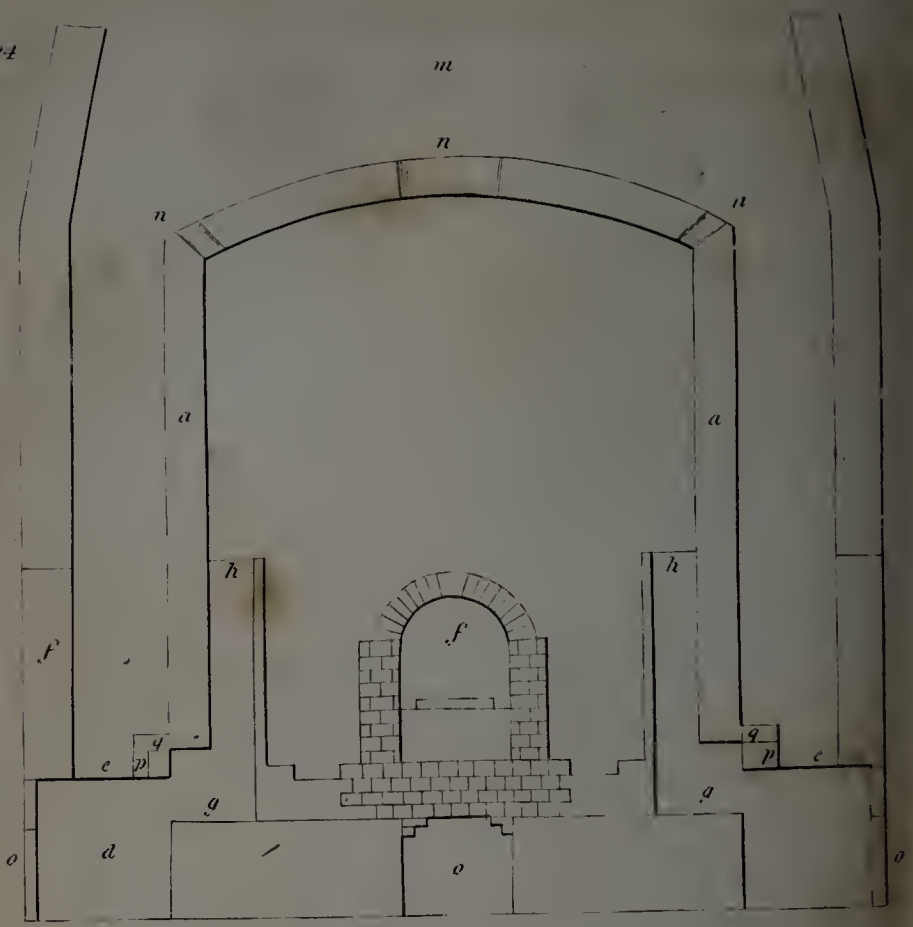
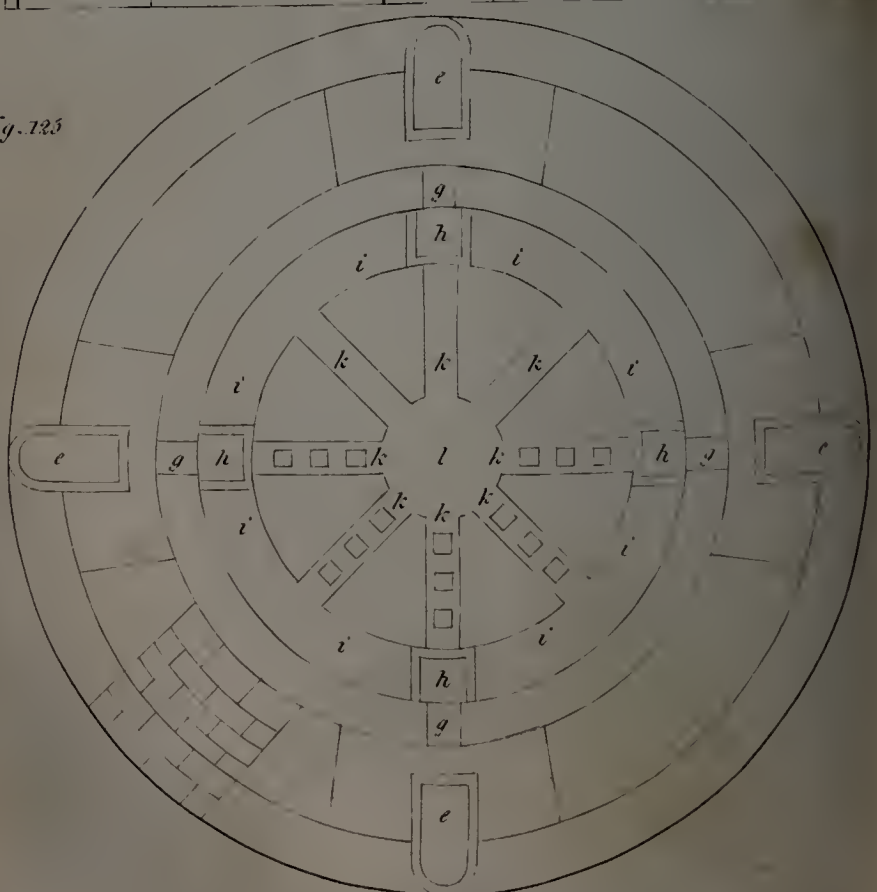



Fig. 125



touch the surrounding wall as would be just sufficient to carry off the waste smoke.

*A*, is the cylindrical wall of the kiln forming the space, *b*, which is the chamber in which the seggars are piled; in it is a doorway through which the seggars are conveyed, the space being built up with brick when the kiln is filled; *d*, in the section are the spaces occupied by the fire which is introduced at the openings, *e*, which open into the arched recesses, *f*, formed in the surrounding wall. The holes, *e*, are surrounded by frames made of earthenware or cast iron, in the shape of a horse shoe.

The flame of the fire enters the horizontal flue, *g*, from whence it is free either to ascend through the chimney, *h*, or branch into the circular flue, *i*, by which it has access by the intermediate flues, *k*, to the central opening, *l*, from whence it rises perpendicularly to the top of the kiln, where it escapes into the chimney, *m*, through the openings, *n*. The fire in these furnaces does not rest upon a grate, but lies upon the ground, the old construction for wood being retained, although coal is now used.

The opening at *o*, during the firing, is built up with bricks, leaving a number of openings for the air to pass through the fire, which is piled up as high as, *e*, in the elevation, and sometimes a little higher. *P*, are large fire bricks, forming a sort of bridge or arch over the opening, *e*, and coming close up to the wall, *a*. At this place a groove made in the bridge forms a perpendicular opening, which is closed by the flat brick, *q*. When this opening is closed, the current of flame is more considerable through the upright chimney, *h*, and less through the horizontal flues, *g* and *i*. The former of these currents, however, is diminished, and the latter increased, by removing the brick, *q*, by which a current of cold air descends through the openings below; by means of this brick the heat is increased at top or bottom of the kiln at pleasure, the uniformity of which is of great consequence.

In the plan, part of the upper floor of the kiln is removed to show the direction of the flues; the fourth quarter being left covered with bricks, as when the seggars are piled upon the floor. In the direction of each of these flues every other brick is left out. This gives the upper floor the appearance of being full of holes, and through these holes the flame rises among the piles of seggars. The seggars being of a circular or elliptical form, although piled close together, leave sufficient interstices for the flame to pass through. The piling is commenced at the opposite side of the kiln to the door-way, *f*, and continued till the last pile is raised close to the entrance, which is then closed up with brick till the firing is completed.

The first firing, or that in the biscuit oven for Staffordshire ware, usually lasts from 48 to 50 hours. Rings of Egyptian black clay are placed in the kiln, as trial pieces, by taking out which the biscuit fireman governs his proceedings.

The biscuit, or once burnt ware, absorbs water, and hence it is used without glazing for wine coolers, and for pots for growing flower roots.

The biscuit is painted previously to its being glazed. Some wares are painted by the pencil. Others have the pattern engraved upon copper plates, and the colouring ingredients, which is mostly oxide of cobalt, are ground with oil to form an ink, with which the engraving being filled, an impression is taken as usual by the rolling press, upon tissue paper, previously brushed over with soft soap water; the impression is trimmed with scissors, and applied to the biscuit. As soon as the ware has imbibed the colour, the paper is washed off with clean wa-

ter, and the ink dried in a kiln. Sometimes the outline of a pattern is printed, and it is filled up with the pencil.

The biscuit is then ready to be glazed, either with a raw or frit glazing.

Raw glazes are generally composed of white lead, Cornish stone, and flint ground; to which metallic oxides are sometimes added, they are used for the more common wares.

Frit glazes are in fact ground coloured glass; Lynn sand is the usual basis, which is fluxed either with soda, or with white lead and flints ground.

The glaze ground with water, is made up to the consistence of cream, and the ale pint of slip usually weighs about 32 ounces. As the ingredients are heavy, the slip must be kept stirred, to prevent them from settling. The biscuit is dipped in this glaze, and turned rapidly about that it may lie evenly on the surface; and as soon as it is dry, it is placed again in seggars, which are piled in the gloss oven.

The gloss oven seldom holds more than half the quantity of ware fired in the biscuit oven; as the fire is quickly raised to the height necessary to melt the glaze, and is usually kept fired from sixteen to nineteen hours. Trial pieces, made of raw red clay, are used to govern the gloss fireman's operations.

The choicest articles of pottery are painted, gilt, or printed black, upon the glaze. The painting is performed by means of metallic oxides; black, by the oxides of iron, cobalt, and copper, mixed together; purple or violet, by oxide of gold, and Cassius' purple precipitate of gold; green, by oxide of copper; and blue, by oxide of cobalt. The colours are ground with oil of turpentine, or oil of tar, and laid on with camel hair pencils.

Gilding is performed by grinding gold separated from aqua regis by copper, along with oil of turpentine, and applying it with a pencil or sponge, upon the ware.

Black printing is performed with glue papers, made by pouring out melted glue into very smooth dishes, so that it may lie to the thickness of about an eighth of an inch; these papers, when cold, are cut into the requisite sizes. The copper plate, having the design engraved upon it, is filled with boiled oil, (without any colour to give it the denomination of ink,) and a piece of glue paper pressed upon it; the oil in the strokes adheres to the glue paper, which is then pressed to the ware, on which it in turn leaves the oil. The colours reduced to very fine powder, are slightly sprinkled on the ware, and adhere to the oil; and when the oil is dry, the remaining colour is carefully wiped off with old silk rags, and the ware fired in the enamel kiln.

The enamel kiln is externally from six to ten feet long, and three to five feet wide; it has two, three, or four fire holes, in which wood is burned, and the flame conducted round an iron muffle, which is usually four feet long, two and a half wide, and three high in the centre of the arch.

The articles are carefully placed in this kiln, until the whole is filled, when the mouth of it is bricked up, a small opening being left, with a stopper fitted to it, for inspecting the progress of the firing, the extraction of the trial pieces, and the uniform heating of the muffle, which is extremely difficult, and require great attention on the part of the fireman. The firing in this kiln usually lasts eight or ten hours.

It is according to these processes that the several kinds of pottery made in Staffordshire are made; they varying only in the ingredients which form the clay, or body of the work, and in the glazes applied to them.

The *common red pottery* is made of brick clay, very slightly fired in the biscuit oven, and glazed transparent with litharge, or black, with galena; this glaze is attacked by acids, and even fat.

*Meigh's red pottery* is made of four parts of common marle, one of red marle, and one of brick clay, and is glazed with glass and Cornish stone, in equal parts; to which, for a black glaze, is added black manganese. This ware is not attacked by acids or fat, and may be used without any hazard for pickle jars.

*Fine red pottery* is made of nearly equal parts of yellow brick clay and red Bradwall wood clay.

*Burnett's red pottery*, from Hallfield colliery marle; by the addition of ochre, their *brown pottery* was formed.

*Stone china* is made of Cornish stone, Cornish clay, blue clay, and flint; the glaze is white lead, glass, Cornish stone, and flint.

*Iron stone china* is very strong; its composition is kept secret by Messrs. Mason.

*Felspar china* is made of Cornish stone, Cornish clay, felspar, and bone ash.

*Cream coloured pottery* is made of blue clay, Cornish clay, flint, and Cornish stone; some add black clay, brown clay, and cracking clay, with but little flint and Cornish stone. It is glazed with Cornish stone, flint, and a small proportion of white lead.

*Blue printed pottery* is made with a greater proportion of blue and porcelain clays, and flint, than the cream pottery; and its glaze is made of glass, white lead, Cornish stone, and flint.

*Semi China* is a ware that approaches to the semi transparency of the oriental porcelain.

*Chalky pottery* is made from Cornish clay, blue clay, Welsh clay, flint, Cornish stone, white enamel tinged with smalt; to which some add, bone ash and plaster of Paris; the biscuit requires a very strong fire. The glaze of this ware is glass, Cornish stone, flint, borax, refined saltpetre, red lead, purified pearl-ash, Lynn sand, carbonate of soda, and zaffre, fritted by a strong fire, then ground and mixed with white lead, glass, flint, and Cornish stone.

*Bamboo ware*, or *cane coloured ware*, is formed of black marle, brown clay, Cornish stone, and shavings of cream coloured pottery; it is never glazed outside, although sometimes the outside is vitrified, the inside is usually glazed with a thin coat of glass.

*Wedgewood's jasper pottery* is formed of blue clay, Cornish clay, sulphate of barytes, flint, and a little plaster of Paris, tinged with zaffre.

*Pearl pottery* is only used for choice articles; it is composed of blue clay, Cornish clay, Cornish stone, a little glass, and red lead.

*Black Egyptian pottery* is made of cream-coloured slip, manganese, and ochre; it is glazed with white lead, Cornish stone, and flint; the inside is washed with white lead, flint, and manganese, to form a glaze for that part.

*Drab pottery* is formed of blue clay, Cornish clay, Bradwall wood clay, Cornish stone, black marle, and a little nickel; the inside is glazed with cream colour slip, flint and Cornish clay. Another kind of drab ware is made of the shavings of cream-coloured ware made into slip, and mixed with nickel.

*Riley's shining black biscuit porcelain*, although not glazed, yet having undergone a high degree of vitrification, has a polished vitrified surface like black coral without any glaze.

*Gold lustre ware* is made of common red clay; the lustre is given it by laying a slip of soot, or lamp black, and when dry, brushing the ware over with precipitated gold, ground with oil of turpentine.

*Silver lustre ware* is made with a common cream-coloured ware; glazed with soot, or lamp black, and when dry, brushing the ware over with precipitated platinum, ground with oil of turpentine.

Dr. Leigh, in his Natural History of Lancashire, says, he has seen black lead mixed with red lead run upon a clay near Haigh, into a glaze scarcely discernible from tortoise-shell; and that it was on a whitish yellowish earth, near the same place, that Mr. Dwight made his first discovery of his most incomparable metal.

### *Oriental Porcelain, or China Ware.*

The oriental porcelain, although its forms do not appear so elegant to our eyes as the European, and the paintings upon it are, according to our notions, deficient in taste; yet, in the more essential qualities of infusibility, and bearing sudden changes of heat or cold, it is hitherto unequalled in Europe, although the German porcelain comes very near it.

The oriental porcelain is made from only two ingredients, namely, 1, kao lin, which is a very dry porcelain clay composed of nearly equal parts of silica and alumina: 2, pe tun tse, which appears to be our felspar, or perhaps cleavelandite, which has lately been distinguished from felspar. These are prepared, mixed, and the air bubbles got rid of, as in other pottery wares. The Chinese manufacturers keep the prepared body for a number of years, laying it up early in life for their sons, and working that left them by their fathers.

The Chinese workmen excel in the throwing of their ware upon the wheel, as may be observed in the extreme thinness of some of the articles imported from thence.

It appears that in China, the thrown ware is only dried in the room in which the kiln is built, and then glazed with pe tun tse made into a slip with a ley of fern ashes. After which, it is painted, and enclosed in seggars, and fired in a kiln, which is much smaller than European kilns, being in the shape of an egg set on end, and having only a single pile of seggars in the direction of its axis. The fuel wood is apparently burnt on a grating of bricks made of coarse porcelain, and the air admitted underneath by a long arched vault, as in glass houses. Hence the manufacturing of their porcelain differs in a remarkable manner from the European, which is always fired before it is glazed.

Marbling is a process applied to China ware, by which it seems to be full of cemented flaws. It is called by the Chinese, who are very fond of it, tson tchi; by us, marbled China ware. It is generally plain white, sometimes blue, and has exactly the appearance of a piece of China which had been first broken, and then had all the pieces cemented in their places again, and covered with the original varnish. The manner of preparing it is easy. Instead of the common glaze of the China ware, they cover this with a slip made of a sort of coarse agates, calcined to a white powder. If the marbled China be desired blue, they first give it a general coat of this colour, by dipping the vessel into a blue glaze; and when this is thoroughly dry, they add another coat of this agate slip.

### *European Porcelain.*

This manufactory is little more than a century old, and was introduced in a curious manner; one Bottger, a German lad, was apprentice to a chemist at Berlin, and became acquainted with an alchemist, who undertook to teach him the art of making gold. Bottger, imagining his fortune was made, ran away into Saxony; this was in 1700; his master discovering him, claimed him, but he obtained protectors in Saxony, who wished to profit by his pretended knowledge; he soon discovered that he had been deceived by his instructor: in the course, however, of some experiments for making crucibles capable of bearing an intense fire, he accidentally discovered a composition of earths that formed porcelain by firing. The first porcelain was made at Dresden, in 1706, of a brownish red colour, but in 1709, Bottger, now become a baron, made the first white porcelain, and in the next year, the manufactory at Misnia was established. The manufacture was afterwards introduced into France, and improved by the Reaumur and Macquer, and has since been brought to England, and practised with great success.

Weber has published an account of the Vienna porcelain, having worked there, as well as in the Thuringian manufactory. The following are the compositions used at Vienna.

| *Gypsum China.* | *No.* 1. | *No.* 2. | *No.* 3. |
|---|---|---|---|
| Passau clay, as the basis | 10 | 100 | 100 |
| Calcined black flints | 9 | 9 | 8 |
| Plaster of Paris | 4 | 5 | 6 |
| Broken porcelain | 7 | 8 | 9 |
| *First glazings of gypsum China.* | | | |
| Calcined flints | 8 | 9 | 10 |
| Broken porcelain | 15 | 16 | 17 |
| Plaster of Paris | 9 | 10 | 11 |
| *Sand-stone China.* | | | |
| Passau clay | 100 | 100 | |
| Porlitz sand-stone | 20 | 20 | |
| Chalk | 0 | 5 | |
| *First Glazings for sand-stone China.* | | | |
| Calcined flints | 11 | 1 | |
| Broken porcelain | 18 | 1 | |
| Plaster of Paris | 12 | 1 | |
| *Biscuit Ware for Statuary Figures which are not to be glazed.* | | | |
| Passau clay | 50 | 2 | |
| Calcined flints | 10 | 10 | |
| Plaster of Paris | 1½ | — | |
| Calcined pebbles | — | 10 | |

These wares are first baked slightly, then glazed with their first glazing, which is fired with a gentle heat. The second

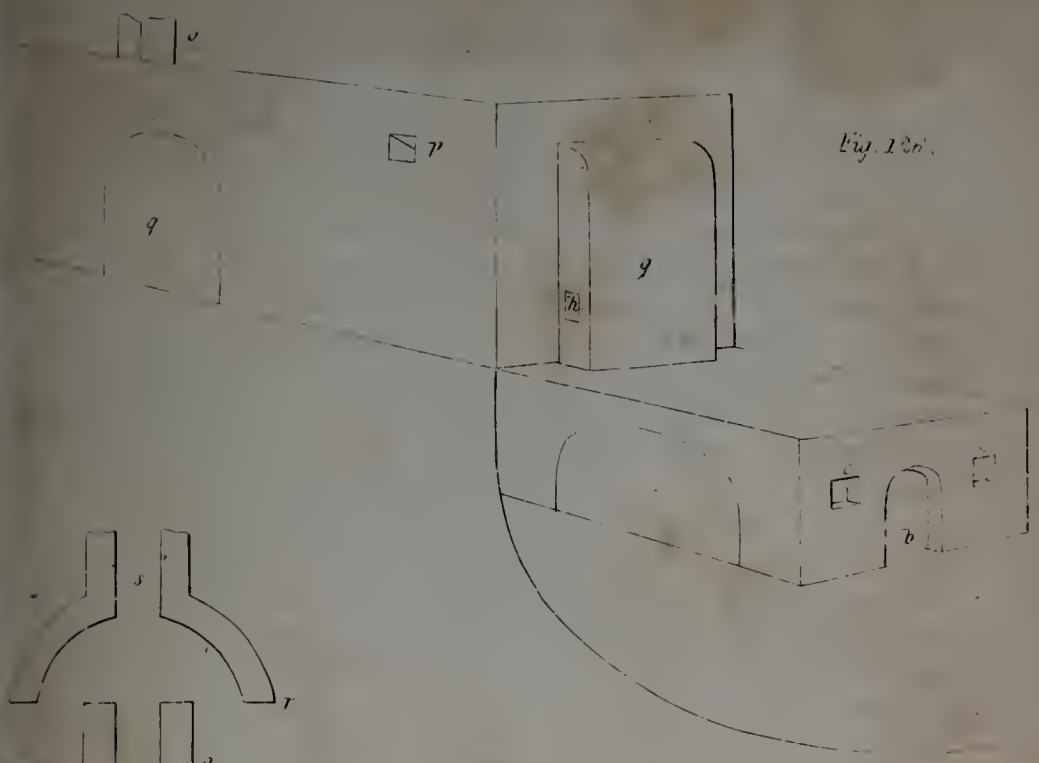



Fig. 126.

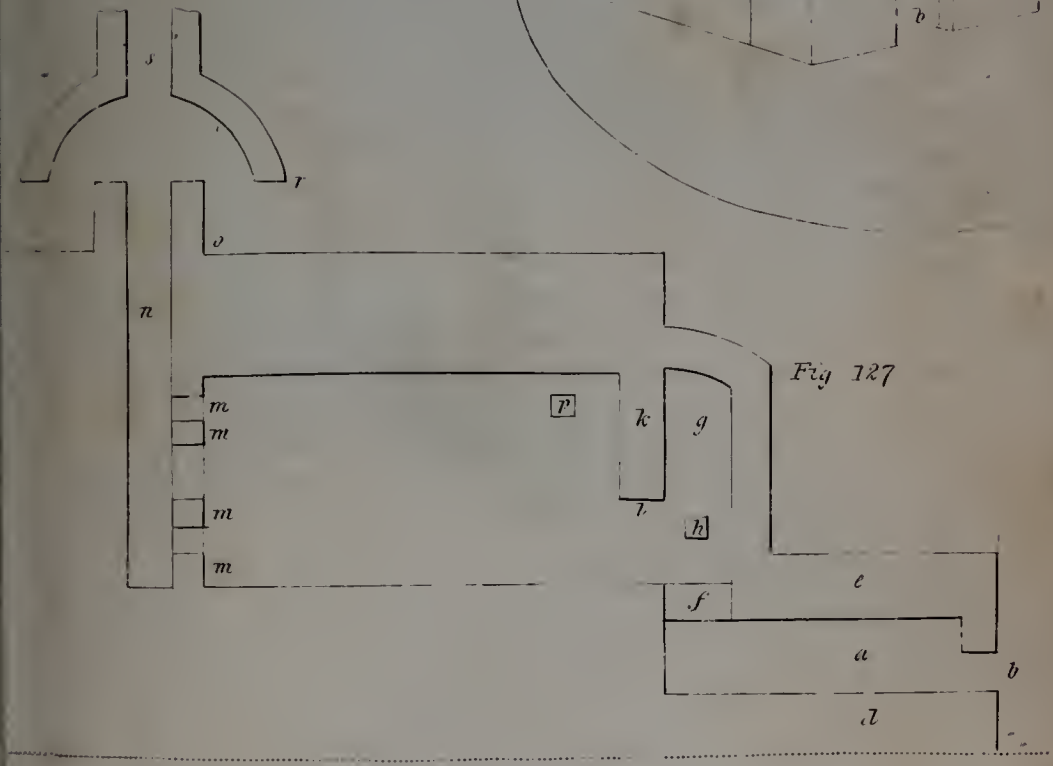



Fig 127

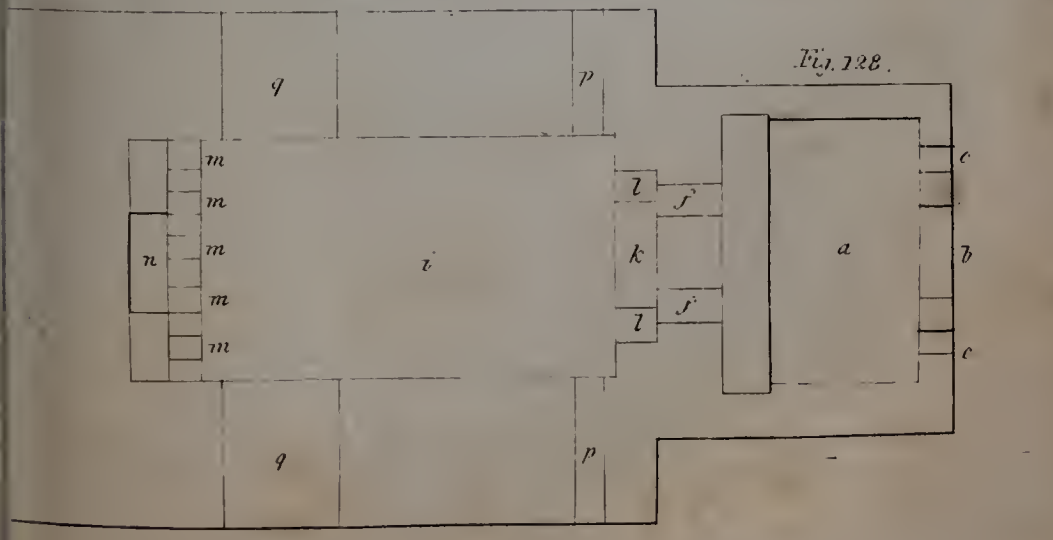



Fig. 128.

glaze, composed of equal parts of Passau clay, Porlitz sandstone, and chalk; to each 100 pounds of which is added one-sixteenth of a pound of borax; is then laid on, and the final firing given.

In the Saxon manufactories, the second glazing is said to be formed of felspar, reduced to a slip by water mixed with a little vinegar, and the ware fired for 30 or 36 hours.

Weber has also given draughts of various potters' kilns, and compared the respective qualities, as to fire room, equality of heat throughout the chamber, passage of the flame, draught, and size of the chamber for the seggars.

The Vienna kiln is simply a parallelopiped chamber, ten feet long, six wide, and three feet high, built on the ground, and having at one of the narrow ends, an open hearth for burning wood, with seven openings, six inches square, even with the floor of the chamber, for the flame and heat to pass into the chamber, from which it issues by a short chimney made in the middle of the roof, at the opposite narrow end.

The French kiln is similar to our own, save that, being smaller, it has only three fires around it, and that it has four short chimneys at top.

The Thuringian kiln is of an excellent construction, and a perspective view is represented in fig. 126, a section in fig. 127, and a plan in fig. 128. The fire room *a*, is six feet wide, as many deep from front to back, and one foot and a half high. The fire door, *b*, is two feet wide, and eight inches high; it is arched at top. On each side of the top of this fire door is a small square opening, *c*, with stoppers, by which the fireman examines the state of the fire. The whole of the fire room is usually sunk in a semicircular pit, so that the roof is level with the floor of the laboratory. It has no grate, but the wood is burnt upon a flat hearth of bricks, *d*, one foot thick, and the low arched roof, *e*, of the fire room, is one foot and a half thick, so that the pit is necessarily four feet deep.

The flame of the wood passes through two holes, *f*, twelve inches wide, and eighteen deep, situated at the extremity of the roof of the fire room, into the immediate chamber, *g*, which is three feet wide, and one foot and a half deep. Its floor, in which these holes are situated, is raised three feet from the ground, so that the roof of the fire room in this place, is six inches thick. This intermediate chamber is four feet high, and its top is turned into a quadrantal arch against the front wall of the main chamber, where it is five feet high. The wall is a foot thick, and it has on each side a spy hole, *h*, about eight inches square, fitted with stoppers.

The main chamber, *i*, in which the seggars are piled, has its floor even with the ground; but this floor is constructed three feet thick of brick work, sunk in the earth. The external dimensions above ground, are eighteen feet long, fourteen wide, and eight feet high. The front wall, *k*, next the intermediate chamber, is one foot thick, and has, even with the floor, two openings, *l*, each two feet and a half high, and a foot wide, to allow the passage of the flame out of the intermediate chamber. The space for the seggars is eleven feet long, six wide, and five high, or 330 cubic feet. Towards the back wall is a partition of brick, a foot broad, having a number of holes, *m*, in quincunx, by which the flame issues out into a flue, *n*, which passes through the roof, and is two feet wide, and one deep, terminating in a chimney, *o*, rising three feet above the roof. The side and end walls of the main chamber are four feet thick, and the roof three. *P*, is an opening, of which there is one on each side, towards the front and top of the chamber, for trial pieces to be taken out occasionally; and *q*, is one of the side doors into the chamber, by which the seggars are put in, after which it is bricked up, and a small opening only left to take out trial pieces.

In order to augment the draught, the chimney is surmounted by a dome, *r*, five feet in diameter, internally, from whence a flue, *s*, proceeds, three feet in diameter, and built as high as convenience will admit.

Da Costa's Natural History of Fossils contains an account of earths and stones, which is highly valuable to the potter, as showing the places where they may be found.

Kirwan's Elements of Mineralogy, details the action of fire upon minerals; but although far more practically useful than any of the later systems of mineralogy, yet it does not descend to the minute details given by Da Costa.

## *Stone Ware.*

This is the poterie de grès of the French chemists; there are two kinds of it, white and brown, but the former is now scarcely used, in consequence of the preference given to blue and white, and painted pottery for dinner services, notwithstanding the superior strength of the white stone ware.

This white stone, or flint ware, is made of tobacco-pipe clay, reduced to a fine slip, and mixed with a slip of calcined flints. The mixture is then dried on a kiln, and beaten to a proper temper, when it is thrown on the wheel, or moulded in a fly press into the proper forms. The ware being dried is enclosed in seggars, having openings in the sides, and fired for about forty-eight hours; common salt is then thrown into the fire, and being reduced to vapour by the heat, its vapour penetrating into the seggars by the openings on the side, promotes the fusion of the surface of the ware, and thus gives it a polished appearance.

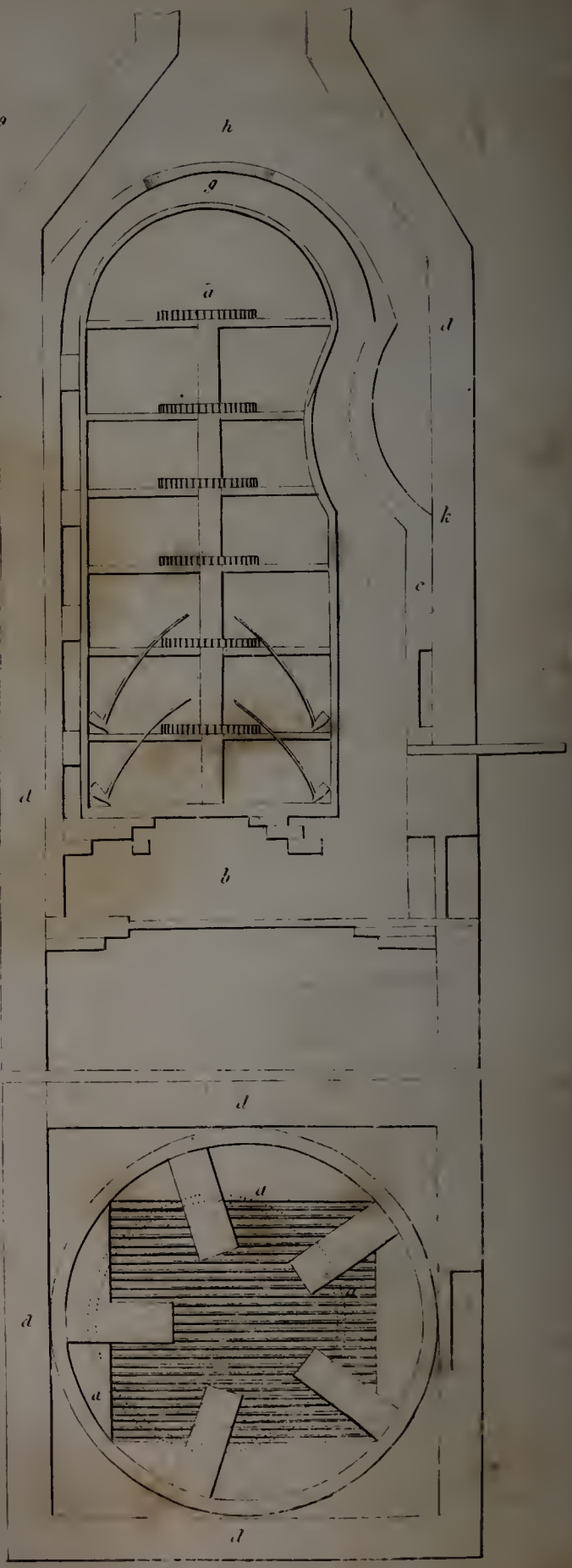
A coarser kind of white stone ware is made of sand instead of calcined flints.

The brown stone ware differs only in respect to the materials, which are a coloured, but equally infusible clay, and sand; it is fired and glazed in the same manner, except that it is not enclosed in seggars, but the kiln is divided into stories by brick floors. There are some clays that do not require the throwing of salt into the fire, but acquire a smooth vitreous surface merely by an increase of the heat, and these clays are preferred by the manufacturer.

The gray Dutch stone ware is superior in strength to the English, and particularly in regard to bearing the exposure to fire.

A kind of stone ware, different from the ordinary ware, is manufactured into retorts and other distilling vessels, which are to be exposed to an intense heat. In this stoneware, a slip of ground vessels, which have failed in the baking, is used in-

Fig. 129



stead of calcined flints or sand; and from its greater infusibility the surface is rough.

Crucibles for containing oxide of lead, or glass containing much of that oxide for a long time in the fire, are made of this composition, and rendered extremely close in their texture, by the material being tempered very stiff, and compressed into form in a fly press.

### *Crucible Ware.*

The object of this ware being to stand considerable heat, its external appearance is not regarded.

Crucibles and other chemical vessels, are usually made of raw and burnt clay, made into thick slips, and mixed in certain proportions. Sometimes this mixed slip is formed immediately into vessels, by casting in plaster moulds, or it is dried to a convenient degree, and then either formed into shape by hand, or thrown on the wheel.

Stourbridge melting pots are made by simply moulding the raw clay into shape by the wetted hands, and then leaving them to dry; hence they are usually kept in the fire an hour before they are charged.

For melting metals, black pots are used, which are made of raw clay mixed with ground refuse black lead, not fit for pencils, nor lustre; and the Sheffield pots of this kind, are made of clay and ground stifled coke; these vessels are thrown on the wheel. They bear sudden alterations of heat better than the other kinds of ware, but when salts are melted in them, the charge soon runs through into the fire.

### *Tobacco Pipes.*

This manufacture is of less extent than the other branches of pottery ware; but the furnace, as used by the English tobacco-pipe makers, is of a very peculiar construction, and in some respects superior to the potters' furnace, as having the fuel supported on a grate.

The pipes themselves are made of clay, which being coloured with bitumen only, burns white in the fire. This clay is moistened with water, and beaten with a staff for a long time, until it becomes uniformly moist, and fit for moulding. The pipes being moulded and dried in the air, are then fired.

In some parts of the Continent, the pipes are enclosed in seggars that are cylindrical, in which the pipes are disposed so that the bowls are next the sides of the seggar, while the stems form a pyramid in the centre. In this case, as the seggars are

placed in piles, it is only the lowermost of each pile that has any bottom; the middle seggar of each pile being open at both ends, and the uppermost covered with a conical cap, in which the stems of the pipes are received. Several piles of these seggars are heaped in a furnace similar to the ordinary potters' kiln, but smaller.

In England, the seggar is constructed in the furnace, and is in fact an inner chamber to it.

Fig. 129, represents this furnace, which is to be admired for the equality of the heat in every part of the crucible or seggar, in which the pipes to be heated are placed, at the same time that the flame is not permitted to enter so as to soil the articles it contains. This crucible or seggar, *a*, is of a cylindrical figure, terminated at the top by a hemisphere; it is placed over the fire-place, *b*, enclosed within a lining of fire-brieks, *c*, and surrounded by an outer case of brick work, *d*. Between the lining, *c*, and the seggar, is a space of about four inches all round, in which the flame from the fire-place circulates without interruption, except what arises from the numerous supports, which are necessary to sustain the seggar in its proper position; but as these are always placed edgeways to the flame, and are very thin, they cause but little obstruction to its action.

These supports are twelve ribs between the seggar and the lining, which form the same number of flues, as shown by the dotted lines. The ribs are perforated with occasional apertures, to connect one flue with the adjoining; but the principal bearing of the seggar is taken from five piers, formed of bricks projecting one over the other. One of these piers is placed at the back of the fire-place, and other four at the sides, and projecting at the top nearly into the centre of the fire-room, so as to support and strengthen the bottom of the seggar, which rests upon these piers. The spaces between which form the mouths or commencement of the flues, all of which unite in the dome, *g*, of the fire brick linings, and this has a circular opening through it, leading into the chimney, *h*.

The lining, *c*, *d*, of the seggar, is open on one side, to form the door at which the pipes are taken in and out of the furnace; the opening is permanently closed as high as *k*, by an iron plate plastered with fire-clay; above this it is left open, and only closed when the furnace is burning by temporary brick work; when this is removed, the furnace can be filled or emptied through the opening. For this purpose, the seggar has a similar opening in its side. When the furnace is burning, the aperture is thus closed, the workman first spreads a layer of clay round the edge of the opening, he then sticks the stem of broken pipes across, from one side to the other, and plasters the interstices with clay, in a manner exactly similar to the lath and plaster used in building. The whole of the seggar is made in this manner, the bottom is composed of a great number of fragments of pipes, radiating to the centre; these are coated with a layer of clay at the circumference, a number of the bowls of broken pipes are inserted into the clay, then other fragments are placed upright, to form the side of the seggar. The ribs round the outside, which form the flues, are constructed in the same manner, as is also the dome, *g*, of the fire-brick lining; by this means the seggar is made very strong, but at the same time so thin, as to require but little clay to construct it, and is less liable to split by the heat than a vessel formed of thicker materials. This method might be advantageously applied in other cases, where a very thin vessel or lining is required for a furnace.

The pipes which are to be baked are arranged within the seggar, the bowls resting against the circumference, and the other ends supported upon circular pieces of clay, *h*, which are set up in the centre for that purpose. Six small ribs are made to project inwards all round the crucible, at the proper height

to support the different ranges of pipes, without having so many resting upon each other, as to endanger their being crushed by the weight. By this mode of arrangement, the furnace is made to contain 50 gross, or 7200 pipes.

These require from seven to nine hours to be burned, and the heat is at first brought on gently, and afterwards increased to the full heat required for baking this species of pottery. The fire is regulated by a simple kind of damper, applied over the aperture in the dome, *g*, of the fire-brick lining. This is a mixture of horse-dung, sand, and pipe-clay, well worked together, and spread in thin layers upon coarse brown paper. A sheet of this being laid over the hole in the dome, so as to cover more or less of it, will give the means of increasing or diminishing the draught, and consequently the heat of the furnace.

## *Bricks.*

The art of brick-making consists chiefly in the preparing and tempering of clay, and in the burning of the bricks; and the quality of the ware depends very much upon the right performance of these operations.

The earth proper for making bricks is a clayey loam, neither abounding too much in argillaceous matter, which causes it to shrink in the drying; nor in sand, which renders the ware heavy and brittle. As the earth before it is wrought is generally brittle and full of extraneous matter, it should be dug some time before it is used; that by being weathered, it may be sufficiently mellowed, and thus facilitate the operation of tempering. For good bricks it should always have one winter's frost, but the longer it lies exposed, and the more it is turned over and wrought with the spade, the better will be the bricks.

The tempering of the clay is performed by the treading of men or oxen, and in some places by means of a clay mill.

The moulding of bricks is a very simple operation, and requires very little skill, unless it be to make the greatest number in the shortest time, and the day's labour of a handy workman, employed from five in the morning until eight at night, is calculated at about 5000. The clay is brought to the moulder's bench in lumps somewhat larger than will fit the mould. The moulder, having dipped his mould into dry sand, works the clay into it, and with a flat smooth stick strikes off the superfluous earth. The bricks are then carried to the hack, and there ranged with great regularity, one above the other a little diagonally, in order to give a free passage to the air. The hacks are several yards long, and usually made eight bricks high, and wide enough to be shifted, which is done by turning them, and resetting them more open; and in six or eight days more they are ready for the fire.

Bricks in this country are generally baked either in a clamp or in a kiln. The latter is the preferable method, as less waste arises, less fuel is consumed, and the bricks are sooner burnt.

The kiln is usually thirteen feet long by ten feet and a half wide, and about twelve feet in height. The walls are one foot two inches thick, carried up a little out of the perpendicular, inclining towards each other at the top. The bricks are placed on flat arches, having holes left in them resembling lattice work; the kiln is then covered with pieces of tiles and bricks, and some wood put in to dry them with a gentle fire. This continues two or three days before they are ready for burning, which is known by the smoke turning from a darkish colour to transparent. The mouth or mouths of the kiln are now dammed up with a shinlog, which is pieces of brick piled one upon another, and closed with wet brick earth, leaving about it just room sufficient to receive a fagot. The fagots are made of furze, fern, or heath, and the kiln is supplied with these until its arches look white and the fire appears at top, upon which the fire is slackened for an hour, and the kiln allowed gradually to cool. This heating and cooling is repeated until the bricks be thoroughly burnt, which is generally done in forty-eight hours. One of these kilns will hold about 20,000 bricks.

Clamps are mostly in use about London. They are made of the bricks themselves, and generally of an oblong form. The foundation is laid with place bricks, that is, the driest of those just made, and then the bricks to be burnt are built up, tier upon tier, as high as the clamp is meant to be, with two or three inches of breeze, or cinders, from whence the ashes have been sifted, strewed between each layer of bricks, and the whole covered with a thick strata of breeze. The fire-place is perpendicular, about three feet high, and generally placed at the west end; and the flues are formed by gathering or arching the bricks over, so as to leave a space between each of nearly a brick wide. The flues run straight through the clamp, and are filled with wood, coals, and breeze, pressed closely together. If the bricks are to be burnt off quickly, which may be done in twenty or thirty days, according as the weather may suit, the flues should be only at about six feet distance: but if there be no immediate hurry, they may be placed nine feet asunder, and the clamp left to burn off slowly.

Coke has been recommended as a more suitable fuel than either coal or wood for this manufacture, both with regard to the expense and the proper burning of the bricks, for if this substance be applied, the flues or empty places of the piles, as well as the strata of the fuel, may be considerably smaller; which, since the legislature calculates the tax on bricks by the measurement of the clamps, is no small consideration; and as the heat produced by coke is more uniform and more intense than what is produced by the other materials, the clamp of bricks has a

better chance of being burnt perfect, throughout the whole clamp.

There are many varieties of bricks, manufactured about London, under the several names of place bricks, gray stocks, red stocks, malm bricks.

Fire bricks are also made, which bear an intense heat without melting. Of this kind are Windsor bricks, made of a red clay from Hedgerley, near Windsor; these bricks are cut or ground nearly as easy as chalk; Stourbridge bricks are, on the contrary, extremely hard, like stoneware, but of a uniform texture and dark colour. Welsh fire clumps resemble ordinary bricks, and are of a very coarse texture.

### *Tiles and Coarse Pottery.*

Tiles differ only from bricks in their shape; but they are always burnt in kilns; which generally resemble potters' ovens, but no seggars are used; the kilns being divided into stories by brick floors, upon which the tiles are piled in the same manner as the stoneware kilns.

Common articles of pottery, as chimney pots, garden pots, pans, pipkins, and such like articles, formed either by hand, or on the wheel, are burned in similar kilns, and some of these wares are glazed, by a slip of litharge, either alone or mixed with black manganese; this glaze is so much acted upon by vinegar, salt, and even fat, that, however averse a person may be to have the legislature interfere in matters of trade, they must acknowledge the propriety of its being prohibited.

### *Delft Ware.*

This is, in fact, only common red pottery enamelled; the ware being first covered with a thick coat of opaque white enamel, coloured with oxide of tin, and then painted with other enamel colours.

Before the invention of European porcelain, Delft ware was its substitute; and the Dutch manufacturers endeavoured to counterbalance the clumsiness of the form, by the pictorial excellence, employing the most celebrated artists. Hence, although the manufacture of it has ceased, yet the specimens of it that remain are sold at very high prices, and valued as reliques of the ancient native arts of Europe.

### *English Alum.*

The greatest alum mine in England is at Whitby, and is of alum slate. The stratum of alum slate is about 29 miles in width, and disposed in horizontal beds; the upper part being the richest, and five times more valuable than that which is taken 100 feet lower.

The slate is burned by breaking it into small pieces, laying a bed of furze, brush wood, and cinders, on the ground, and

piling the slate upon it to the height of about four feet. Fire is then set to the fuel, and fresh slate thrown on the pile, until the heap is raised to the height of 90 or 100 feet, and 200 feet square at bottom. If the fire grows too fierce, its rapidity is checked by throwing on the places slate broke into very small pieces and moistened. On an average, 150 tons of calcined alum slate produce a ton of alum.

The calcined slate is washed four times successively, in pits which usually contain about 60 cubic yards: the water being passed through the most exhausted slate first, and through new slate last: remaining on each for a day and a night. The ley is drawn off into cisterns to settle, and afterwards reduced in quantity by heating in large leaden boilers, set on a gentle slope, upon iron plates.

The pans are filled two-thirds with the mother liquor of the crystallizing cisterns, and one-third of fresh made ley, and evaporated, until, in the secret language of the manufacturers, it weighs 36 pounds.

The alum makers' weight was considered a great secret, and passed hereditarily in families, or was sold for considerable sums of money: in the same manner as supposed secrets are still sold in many of our manufacturing towns, and even in London, although they have been repeatedly described in print, so that the buyers may be said not to buy a secret, but to pay, and very dearly too, for their neglect of reading works on their respective arts.

The alum makers' weight is only a statical mode of ascertaining the specific gravity of the leys. A stoneware half-pint bottle is taken and weighed. It is then filled with rain water and weighed again, and a lead or brass counterpoise made to it. The weight of the water which it contains is divided into eighty parts, which are called indifferently penny weights, or pounds, and a pile of weights are adjusted to these denominations; so that the penny weights or pounds that a liquor is said to weigh, in the alum and copperas works, means so many eightieth parts above the specific gravity of water.

The strength of the ley above-mentioned is therefore 1·45, and at this period kelp ley, weighing two pounds, or 1·025 is added in sufficient quantity to reduce the alum ley to 27 pounds, or 1·3375. The ley is then run off into settling cisterns, and from thence to crystallizing cisterns. When the ley is very red, urine is added to reduce it, as well as kelp ley.

After standing four days, the mother water is pumped off into the boilers; the alum crystals are slightly washed, drained, and then dissolved in the smallest possible quantity of boiling water, and the ley run off into large casks, where it remains for a fortnight. The casks are then taken to pieces, and the roched alum is found in a solid mass, with a cavity in the centre. Seventy-three tons of kelp are generally required for crystallizing 100 tons of alum; or, instead of kelp, about 22 tons of muriate of potasse from the soap boilers, or 31 tons of black ash, may be used for the same purpose, and indeed with more advantage,

as the muriate of iron is an uncrystallizable salt, and therefore less apt to foul the alum or impregnate it with iron. Hence, these are used by many manufacturers.

### *French Alum.*

The pure sulphate of alumine does not crystallize without the admixture of potasse or ammonia; to introduce these alkalies, our own manufacturers use kelp, black ash, and urine; but the French have introduced the use of the sal enixum, or sulphate of potasse of the manufacturers of aqua fortis or nitric acid, that of the sulphate of potasse, which is the residuum of the oil of vitriol houses; and that of the sulphate of ammonia prepared from rough bone spirit, saturated with oil of vitriol; to these may be added the sulphate of ammonia prepared from ammoniacal liquor of the gas works.

As these articles are of different prices at different places, and also as they are not always of the same degree of power, it is necessary to ascertain the quantity of alum that they will yield with the alum liquor of the works.

For this purpose 2 ounces of a fair average specimen of the salt is ground in a mortar, and 48 ounces, that is to say, three pounds of alum liquor, thoroughly saturated, and being generally the mother water of some liquor that has been crystallized, is added; the mixture is the heated till it boils, and immediately covered up and set by in a cellar to crystallize.

The crystals are carefully collected, placed upon a filter, left twenty-four hours to drain, then washed half-a-dozen times with a saturated solution of alum, drained each time for an hour; then dried with blotting paper, and at last weighed.

The pure sal enixum, or sulphate of potasse of the aqua fortis makers, generally produces nine ounces, or four times and a half of its own weight of alum.

The sulphate of potasse from the oil of vitriol makers varies very much and produces from one ounce to three of alum, or from one-half to one and a half its own weight.

The sulphate of ammonia from bone spirit produces twelve ounces of alum, or six times its weight.

The impure sub carbonates of potasse, or the different kinds of kelp, vary greatly, as do also the impure muriates of potasse.

It is usual in France to employ both sulphate of potasse and sulphate of ammonia, if they can be procured at a reasonable price; but the manufacturers cannot always obtain the latter.

The use of sulphate of ammonia is indeed more expensive than that of an equivalent crystallizing quantity of sulphate of potasse, but this greater expense is compensated by the saving of fuel and labour. This saving depends upon the solubility of sulphates of ammonia being much greater than that of sulphates of potasse. Hence the use of sulphate of ammonia as a crystallizer in alum works, allows it to be added to a very high charged alum liquor; by which means an abundant separation

of small crystals of alum takes place immediately, without any fire, but this effect cannot be obtained by the use of sulphate of potasse, which takes too much water to dissolve it. However, the solution of this salt may be used to dissolve the sulphate of ammonia, and by this means one-fifth of sulphate of potasse may be used along with sulphate of ammonia, without its being necessary to increase the quantity of water to be added to the alum liquor, and thus obliging the manufacturer to boil away the overplus. It is however proper to warm the liquor to 68 degrees Fahrenheit, and then add the solution of sulphate of ammonia; crystals of alum soon begin to separate, and on the crystallization being finished they are to be washed.

When sulphate of ammonia cannot be obtained at a reasonable price, or the cheapness of the other crystallizers lead to their use, then it is proper to dissolve the sulphate of potasse in water kept boiling, and to pour this into the alum liquor, boiled as high as possible, and also hot, then to cool the mixed liquors quickly, to cause the alum to crystallize in small crystals. Another method of using the sulphate of potasse is to grind it very fine, and to add it gradually to the alum liquor by means of a hopper, with a very small opening at bottom. By this means the necessary quantity of sulphate of potasse may be added without the addition of so much water as would otherwise be necessary; the sulphate of potasse becoming united with the sulphate of alumine into alum as fast as it dissolves in the water.

The mother waters and the washings are used to pass through the alum ores, and form fresh alum liquor, until they become too highly charged with sulphate of iron, when they may be used for the manufactory of copperas or green vitriol.

A great object in managing alum is always to dissolve it in the smallest possible quantity of water, as in roching it for sale; for every time that alum is dissolved in a large quantity of water, for the purpose of re-crystallizing it, a sub-sulphate of alumine separates in form of a white powder, which is calculated at two per cent. on the re-crystallized alum.

If alum is dissolved in a quantity of water so as to produce a solution at 25 or 30 degrees of Baumé, or a specific gravity of 1·196 or 1·244, the crystals are smaller, more regular, and fetch in France a higher price, by one-fifth, under the idea that they are purer, whence they are called alun fin; and begin to be used by the French dyers instead of the Italian alum.

Some French alum is made from clay dried, ground very fine, and exposed to the vapour of sulphuric acid, in chambers similar to those used in the manufactory of sulphuric acid itself. In this case kelp is usually added in the first instance to

the clay, before it is exposed to the action of the sulphuric acid, and thus the double sulphate, or alum, is formed at once. This is afterwards washed out of the clay, as from an ore, boiled down and crystallized as usual. This is a more simple method than the common, but it has no advantage in a commercial view.

[Curaudau has lately recommended a process for making alum without evaporation. 100 parts of clay and five of muriate of soda are kneaded into a paste with water, and formed into loaves. With these a reverberatory furnace is filled, and a brisk fire is kept up for two hours. Being powdered and put into a sound cask, one-fourth of their weight of sulphuric acid is poured over them by degrees, stirring the mixture well at each addition. As soon as the muriatic gas is dissipated a quantity of water equal to the acid is added, and the mixture stirred as before. When the heat is abated, a little more water is poured in; and this is repeated till eight or ten times as much water as there was of acid is added. When the whole has settled, the clear liquor is drawn off into leaden vessels, and a quantity of water equal to this liquor is poured on the sediment. The two liquors being mixed, a solution of potash is added to them, the alkali in which is equal to one-fourth of the weight of the sulphuric acid. Sulphate of potash may be used; but twice as much of this as of the alkali is necessary. After a certain time the liquor, by cooling, affords crystals of alum equal to three times the weight of the acid used. It is refined by dissolving it in the smallest possible quantity of water. The residue may be washed with more water to be employed in lixiviating a fresh portion of the ingredients. As the mother water still contains alum with sulphate of iron very much oxided, it is well adapted to the fabrication of Prussian blue. This mode of making alum, is particularly advantageous to the manufacturers of Prussian blue, as they may calcine their clay at the same time with their animal matters, without additional expense: they will have no need in this case to add potash; and the presence of iron instead of being injurious, will be very useful. If they wished to make alum for sale, they might use the solution of sulphate of potash, arising from the washing of their Prussian blue, instead of water, to dissolve the combination of alumina and sulphuric acid. Ure's Chem. Dic. Art. Alum.

A practical chemist of Manchester in England, Dr. Warwick, has adopted the following method for making alum:—Take pipe clay and concentrated oil of vitriol in the proportions of 112 pounds of the former, and 72 pounds of the latter; pulverize the clay finely, and mix it into a stiff paste with

the oil of vitriol; make the paste into balls of 6 or 8 pounds each, and sprinkle them over with a little of the dry pulverized clay. Put the balls thus prepared into cylinders of the same form and dimensions as those represented in fig. 104, and close up every aperture, except a small one for the escape of moisture; then expose them to a strong heat for 6 or 8 hours; withdraw the lumps from the cylinder, break them in pieces, and expose them to the air for three or four days. Take 6 cwt. of this mixture and lay it into a leaden vessel, capable of holding four hundred gallons. Pour as much water upon it as will cover it, and stir it occasionally for two or three hours. Then fill the vessel and stir it well. Let the insoluble parts subside, and evaporate the clear liquor in a leaden boiler, until it have a specific gravity of 1·250, when boiling hot, then dissolve as much sal enixum (what remains in the retort after the distillation of nitric acid from nitrate of potash and sulphuric acid,) as will raise the specific gravity to 1·310. The liquor is then allowed to cool and crystallize. The freedom of the alum from iron is obtained in this way, will depend upon the purity of the clay in this respect. The iron obtained from this source may be precipitated from the solution before concentration, by the prussiate of potash, and the Prussian blue, thus formed, be reserved and dried for sale.

Another process for the manufacture of this important salt, is carried on in connexion with the manufacture of oil of vitriol. The product of the combustion of sulphur with nitrate of potash and pipe clay, contains, in fact, a considerable portion of alum ready formed; but by exposure to the air and moisture, the whole of the sulphur which remains in the clay becomes acidified, and unites with the clay. The sulphate of potash formed by the union of a portion of the sulphuric acid, formed in the combustion with the base of the nitre, answers the purpose of a pure alkali in aciding the crystallization, to which it is usual to add the sal enixum, from the distillation of nitric acid as above. The alum is dissolved out by leaching or otherwise, and the salt crystallized from the concentrated solution. A large proportion of the alum manufactured in the United States, is obtained in this way. The writer is not particularly acquainted with the details of this process; but the foregoing, he believes, is substantially correct.]

Most alum contains more or less sulphate of iron, although seldom more than one-tenth per cent.; yet this small quantity produces perceptible effects in dyeing; hence Dr. Thomson thinks it might answer to dissolve clay, perfectly free from iron, in sulphuric acid, and crystallize the solution by the addition of the usual salts.

### *Italian Alum.*

In the alum works at Tolfa the ore is blasted, then separated from the rock that adheres to it, and calcined in furnaces similar to lime kilns, for five or six hours. The calcined ore is laid in heaps upon a paved floor, surrounded with ditches, out of which, water is flung upon it daily for six weeks. The water is then evaporated by boiling, and crystallized by cooling in large pans.

At Solfatara, a concealed volcano near Puzzuolo, sulphureous and sulphurous acid fumes are constantly discharged from the ground; the former condense into native sulphur, or rough brimstone; the latter act upon the lava rocks, and combining with the alumine form efflorescences; the washings of these efflorescences, and also of the calcined ore, similar to that of Tolfa, which is also found in the neighbourhood, is evaporated in leaden cisterns, sunk in the ground, which being here of the temperature of 104 degrees Fahrenheit, no fuel is required. The alum made in this manufactory is very pure.

Alum is greatly used in dyeing and calico printing, being one of the principal preparatives for the colours. It is also the basis of several lakes, or body colours used by painters. Tanners also use it to harden their hides, and tallow melters to harden tallow; in medicine it is also used with views nearly similar.

Alum is a triple salt, consisting essentially of sulphuric acid and alumine, rendered soluble in water, sometimes by potasse, sometimes by ammonia, according to the materials used in its manufacture: these salts are however so similar in their appearance and properties that they are not usually distinguished, except by dyers.

The ammonia sulphate of alumine, or the sulphas aluminico ammonicus of Berzelius, is stated by him to consist of $N\cdot H^6 S:\cdot + Al:\cdot S:\cdot^3$, and its atomic weight to be 2,861,540. According to Dr. Thomson its composition is $3\ (S:\cdot Al\cdot) + S:\cdot Az\ H^3 + 25\ H\cdot$, equal to 57,000.

The potasse sulphate of alumine, which is that commonly sold as alum, or the sulphas aluminico kalicus cum aquâ of Berzelius, is stated by him to consist of $K: S:\cdot^2 Al:\cdot S:\cdot^3 + 48\ (H_2O,)$ and its weight 11,870,770. Dr. Thomson makes it, $3\ (S:\cdot Al\cdot) + S:\cdot K\cdot + 25\ (H\cdot)$ equal to 60,875; so that he supposes it differs only from the ammonia alum in having an atom of sulphate of potasse substituted for the atom of sulphate of ammonia, which is imagined to be combined with the three atoms of sulphate of alumine and twenty-five of water.

The potasse alum is rather more soluble in water than the ammonia alum; for 100 parts of water at 60 degrees Fahrenheit, will dissolve 14 parts three-fourths of potasse alum, and only 9 parts one third of ammonia alum.

### *Soda Alum.*

The sulphate of alumine may also be crystallized, by adding soda, or soda salts, to the ley of alum slate.

It cannot be distinguished in appearance from the common alums, and if pure undergoes no alteration by exposure to the air; when impure it is easily crushed between the fingers, and its surface soon becomes powdery in the air. 100 parts of water dissolve no less than 327 of soda alum, so that it will be far more

convenient for dyers and calico printers, when it is brought into the market, but it has not hitherto been manufactured on a large scale.

### *Acetate of Alumine.*

This is prepared in large quantities for the calico printers, generally by pouring a solution of 70 pounds in potash alum into a solution of 100 pounds of sugar of lead, and decanting off the liquid portion.

It is now sometimes prepared for inferior work, by adding a saturated solution of quicklime in pyroligneous acid, so diluted with water as to have the specific gravity of about 1·050, to a solution of alum, in the proportion of four gallons of the acetate of lime water to each eleven pounds of alum employed; and separating the sulphate of lime that falls down, by straining off the liquor.

Acetate of alumine is employed instead of alum, as a preferable preparative in dyeing and calico printing.

## MAGNESIA.

Some chemists rank this among alkalies, but it is nearly totally insoluble in water; it is the *calcined magnesia* of the shops, so called because it is prepared by heating the ordinary magnesia alba in a crucible, until the carbonic acid and water of the latter is expelled.

Calcined magnesia, as thus obtained, is a white powder, but its proper colour seems to be green; for when stones or earths have this colour, the analytical chemist shrewdly guesses them to contain this earth; and medical men have observed that magnesia exhibited as a medicine frequently produces green stools.

Calcined magnesia is of no use but in medicine; it is supposed by the theorists to be the oxide of a metal they call magnesium. Berzelius imagines it to be Mg: and its weight equal to 516,720; but Dr. Thomson supposes it to be Mg· and its weight 2,500.

### *Magnesia Alba.*

This is obtained from Epsom salt, by adding to its solution in water a ley of purified pearl-ash.

Its composition varies much, according to the quantity of water, and the heat that is employed. Berzelius analyzed a specimen, and found 100 parts of it to contain 44·75 of magnesia, 35·77 of carbonic acid, and 19·48 of water; hence he considers it as 3 Mg: C:2 + Mg: Aq$^8$, and calls it hydro carbonas magnesicus, its weight being 4,618,343. Dr. Thomson is inclined to think it is 3 Mg· C + 4 Mg· H·, equal to 22,750; but Mr. Phillips states it, in his Pharm. Lond. to be the anhydrous carbonate, or Mg· C: and its atomic weight 42 of his scale equal to 5,250 of Dr. Thomson's scale.

Magnesia alba is called magnesiæ subcarbonas by the English medical faculty, and is used as a laxative and absorbent.

## *Epsom Salt.*

This salt was originally crystallized from the mineral water of Epsom, near London; and is the *sulphate of magnesia* of the southern theorists, but called, by Berzelius and the northern chemists, *sulphas magnesicus.*

A large quantity of it is manufactured from sea water, as stated in p. 360; but as the salt thus made is mixed with muriate of magnesia, it grows moist in the air; Dr. Henry, to avoid this defect, manufactured it by several other processes as follow.

He exposed the caustic magnesian lime prepared by burning or calcining the stone, called magnesian lime-stone, to the atmosphere for some time, and passed the slaked lime through a fine wire sieve.

When the acetous or pyroligneous acid is to be employed, the quantity of magnesian lime, or of its hydrate, sufficient to saturate a gallon of the acid, must be first ascertained, and twice as much of the magnesian lime is then added, or else of its slaked hydrate, as is necessary for the saturation. After about four hours, the supernatant liquor is decanted, and may be applied to any of the purposes to which acetate of lime, which is the substance held in solution in the liquor, is adapted. The undissolved portion is chiefly magnesia. This magnesia is calcined at a low red heat, with free access of air, to burn away completely the tarry, rosinous, and vegetable colouring matter with which it is contaminated. On any quantity of the calcined magnesia, reduced to a fine powder, and diffused through water, in the proportion of half a pound to each gallon of water, oil of vitriol, diluted with five or six times its weight of water, is poured. Instead of adding oil of vitriol to the calcined magnesia, copperas may be dissolved in eight times its weight of water; and to the solution a quantity of the calcined product, finely pulverized, and equal in weight to about one-third part of the sulphate of iron, may be added, assaying by means of any of the known chemical tests for iron, a portion of the liquor first cleared by standing; and if the whole of the sulphate of iron proves not to be decomposed, more of the calcined product is mixed with the liquor, until the decomposition of the sulphate of iron or copperas is complete.

By either of these processes a solution of sulphate of magnesia is obtained, which is crystallized by evaporation, there being added, when the liquor has been boiled down to one-third, either magnesia alba in the proportion of about one ounce to every five wine gallons of the liquor, or calcined magnesia in

the proportion of about an ounce to every ten wine gallons of the liquor.

In like manner, when the nitric or muriatic acid may be used, first determining, by a previous experiment, how much of either of the acids is sufficient for the saturation of a given weight of the slaked magnesian lime. This quantity of either of the acids, previously diluted with ten or twelve times its weight of water, is then mixed with twice as much of the slaked magnesian lime as is necessary to saturate the acid.

The magnesian lime may also be acted upon by means of muriate of magnesia, or the bittern that remains after the common salt and Epsom salt have been separated from sea water. A quantity of the bittern, containing a known weight of solid muriate of magnesia, as obtainable by evaporation to dryness, is added to an equal weight of the slaked magnesian lime, the supernatant muriate of lime is decanted, and the sediment washed repeatedly with water till the water comes off tasteless. Oil of vitriol diluted with water is then added to the sediment, till there is a slight excess of acid, which excess is saturated by magnesia alba, and the solution crystallized as usual; or, instead of oil of vitriol, sulphate of iron in the proportion of three parts of copperas to one part of the sediment, may be used. By the use of this bittern, or muriate of magnesia, not only the magnesia which formed a constituent part of the magnesian lime is obtained; but also a farther quantity of magnesia, precipitated from the bittern by the calcareous part of the magnesian lime.

Any quantity of sal ammoniac may be dissolved in ten times its weight of hot water, and as much of the slaked magnesian lime as is equal to the weight of the sal ammoniac added; clear liquor being decanted, and submitted to distillation, yields ammonia water, and the sediment from which the liquor has been decanted, washed repeatedly with water, and acted upon, either with oil of vitriol diluted with water, or with a solution of copperas, yields Epsom salt.

Oxymuriatic acid, or chlorine, may also be employed, by regulating the proportion of oxymuriatic acid, or chlorine, to the slaked magnesian lime, by adjusting the quantity of materials which are used, to afford the gas to the quantity of magnesian lime employed to condense the gas. The general proportion is, for every bushel of common salt, fifty-six pounds of oil of vitriol, at 1·850, forty wine pints of water, and forty pounds of finely ground manganese. And, for every bushel of common salt, at least twenty-eight pounds of the slaked magnesian lime, may be placed in a dry state, in a proper receiver, or suspended in water. The liquid oxymuriates of lime

is decanted off, the insoluble part washed repeatedly with water, and afterwards acted upon in the manner already mentioned, either with dilute sulphuric acid, or with sulphate of iron.

Dr. Henry considered oil of vitriol, whenever it can be obtained at a reasonable price, to be much more fit than copperas, for the purpose of preparing Epsom salt.

Epsom salt is, according to Berzelius, Mg: S:·2+10 HH·, and of course 2,643,390; but Dr. Thomson makes it, Mg· S:· +7 H·, equal to 15,375.

### *Floating Bricks.*

Bricks so light as to swim upon water are a very ancient manufactory, although not yet introduced into this country. Pliny informs us they were made in his time, at Marseilles in France, Colento in Spain, and Pitane in Asia; and Sign. Fabroni has lately made them in Tuscany.

The earth from which they are manufactured, is that called mineral agarie, guhr, lac lunæ, or fossil meal, and that used by Sign. Fabroni, was dug near Castel del Piano, in the Siennese; 100 parts of it contained 55 of silica, 15 of magnesia, 14 of water, 12 of alumine, 3 of oxide of lime, and one of iron. It is not fusible, but loses one eighth of its weight in the fire, without any diminution of its bulk.

Bricks made of this earth, either baked, or unbaked, float upon water, and even one-twentieth of clay, may be added to it, without causing them to sink. They do not imbibe water, and cement well with mortar; the baked bricks differ only from the unbaked, by becoming sonorous. A brick seven inches long, four and a half broad, and one eight-twelfths thick, weighed only 14 ounces one-fourth, while a common brick, of the same size, weighed five pounds, six ounces, and three-fourths. They conduct heat very badly.

Sign. Fabroni recommends these bricks for cooking-places in ships, and to line floating batteries. He thinks the turrets, mentioned to have been built on the ancient ships, may have been constructed with them; and that they were perhaps used in the celebrated ship sent by Hiero, to Ptolemy, as it is said to have had several porticoes, baths, halls, and other apartments, ornamented with mosaic work, agates, and jasper.

## METALS.

Metals have, in all ages, formed the favourite subjects on which chemists have laboured; indeed, at one time, the knowledge of them constituted the whole of what was understood by the name of chemistry. Their extensive usefulness in the arts, and their intimate connexion with the civilized state of mankind, justify this favouritism. Without bronze or steel, for forming cutting instruments, how imperfect would be the state of the arts; without gold or silver, as common scales of value, how imperfect would be the state of commercial transactions. Gold, indeed, is found in the sands of rivers, but its purity must be ascertained: the other three necessaries of civilization, require preparation by chemical operations.

Seven metals have been known for ages, and as this number coincided with that of the planets then known, and the principal cultivators of chemistry were the priesthood, they mystified the laity by using the names of the planets as nicknames of the metals.

The use of gold and silver, as commercial mediums of valuation, and their great value, joined with the numerous chemical analogies between the metals in general, led the chemists, in the earlier period of the science, to suppose that they all consisted of a few elements conjoined in various proportions, and hence to attempt the problem, of changing metals of inferior value, into those of greater value, by altering the proportion of the supposed elements. That they are compounds of a few elements in different proportions, is still probable, but the metals resist the action of such powerful agents, without alteration, that the changing of them into one another, is a problem utterly hopeless of solution by any train of reasoning; chance alone can resolve it.

The number of the metals has been greatly increased of late years, by the analytical chemists, and is by some stated at forty-two; but some of these are little better than hypothetical assumptions, and two of the number, namely, potassium and sodium, are so different from every thing that a practical man would call a metal, that nothing but the rage of the day for the invention of new metals could have prompted their insertion in the list; such indeed was this rage, that hydrogen gas was pronounced to be a metal, just as at present, every organic principle that can be combined with an acid, is called a new alkali.

Metals are the heaviest of bodies, being from six to twenty-one times as heavy as water. Their great use, arises from the generality of them being either capable of being spread out by the hammer or rollers, or being drawn into wire, or capable of being cast into form, by melting and running into moulds; there are indeed some, that are intractable by any of these methods, but their combinations are of great use as colours, or for other purposes.

Of these metals, quicksilver is always in England in a melted state; but in the northern countries sometimes solid, cadmium, copper, gold, iridium, iron, lead, nickel, osmium, palladium, platinum, silver, tin, and zinc or spelter, may be rolled into plates, or drawn into wire; regulus of antimony, arsenic, bismuth, and tellurium, may be cast; but cerium, chromium, cobalt, columbium, manganese, molybdenum, rhodium, tungsten, titanium, and uranium, require a heat for their fusion, which is at present

beyond that of our furnaces; but some of them are brought into use by their admixture with other metals.

## *Mines.*

Some of the metals are found as natives of the earth, but the generality are in a combined state with other principles, and must be separated by art. These combinations are called the ores of the metals, and either form great beds in the earth, or, which is most usual, are found in cracks of the earth, called veins.

When the ores are found in beds, or large masses, under ground, they are extracted in the same manner as rock salt, already described in p. 355, and of which a draught has been given in fig. 111. Sometimes this kind of mine is worked in the manner of a stone quarry, by merely cutting out the ore, leaving pillars or walls to support the roof; or the covering of earth being removed, the ore is cut out like slates from their beds, in steps or banks.

As a specimen of the manner of extracting the ores which are found in veins, the mode of working the Cornish mines may be described.

The veins, or, as they are provincially called, lodes, generally run in an east and west direction. These lodes vary considerably in breadth, and the average may be taken at from one foot to four feet; for in some cases they are only a barley corn in width; while in Nangiles mine the lode is in some places 30 feet wide; and for about the length of 20 fathoms, in Relistian mine, the lode is even 36 feet wide. The width of a lode is by no means regular, for it will vary from six inches to two feet in the space of a few fathoms.

No instance has yet occurred of any lode having been cut out in depth. The deepest mine now at work is Dolcoath; so named from an old woman, Dorothy Koath, who lived on the spot when the working of the mine commenced. This mine is about 235 fathoms deep, and as the counting house belonging to it is 360 feet above the level of the sea, the mine extends 1050 feet below it; which is probably deeper below the level of the sea than any other mine that has been worked. Crenver and Oatfield have lately stopped working, or they would excel Dolcoath in depth, for they are cut down 240 fathoms.

The east and west lodes are cut by others, called cross courses, which run north and south, and do not cause an interruption to the lode, but alter their position, so that the miners must search generally to the right hand to find them again;

it is very rarely that left handed heaves occur. These heaves occasion much trouble to the miners; in Huel Peever it took a search of forty years to recover the lode.

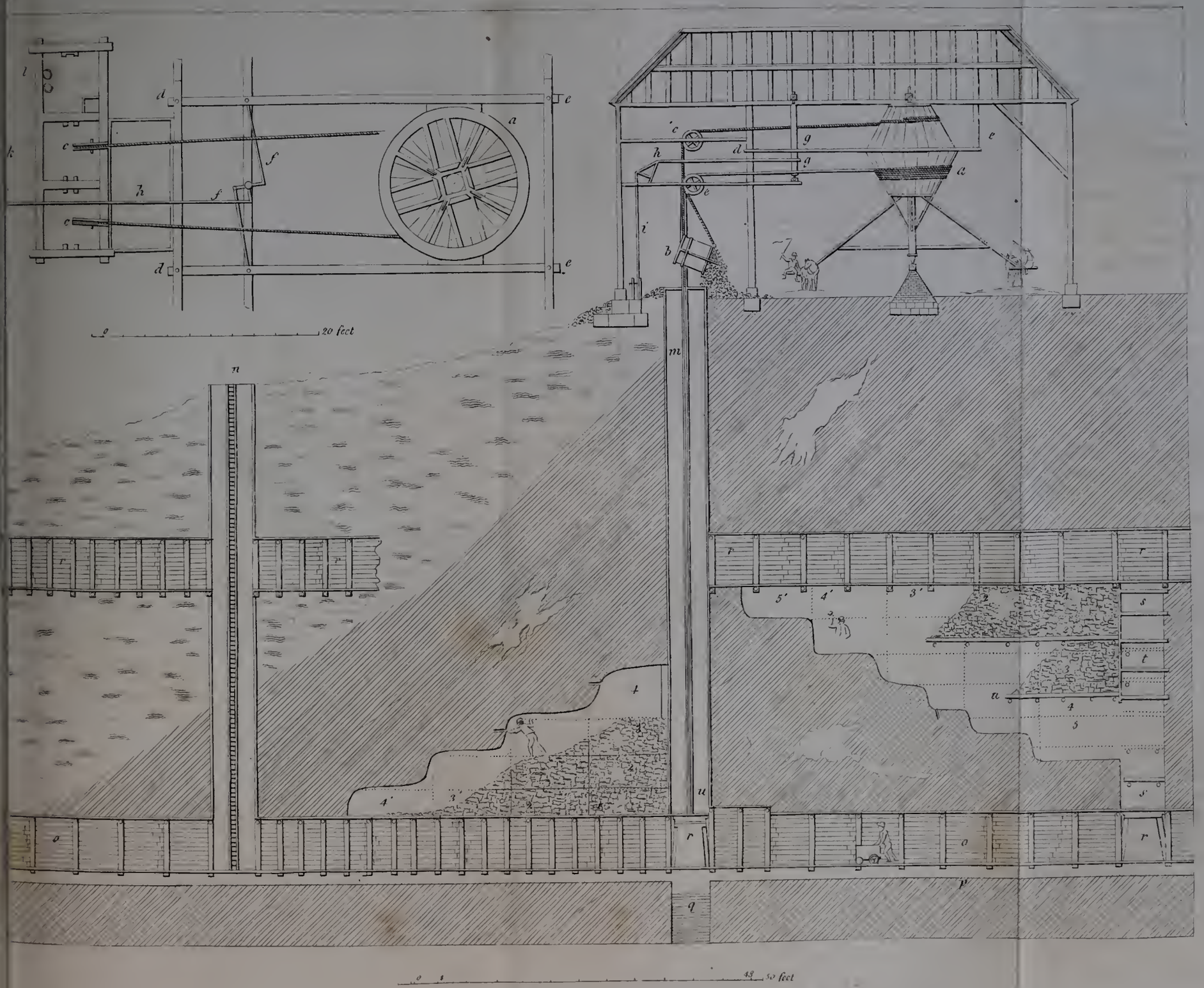
When adventurers determine to work a mine, and have agreed with the proprietor of the soil respecting his share or dish, three points are to be considered: 1. The discharge of the water that may be met with. 2. The removal of the deads, that is the barren rock and rubbish. 3. The raising of the ore. The first object, therefore, is to cut an adit, or underground passage about six feet high and two feet and a half wide, from the bottom of some neighbouring valley up to the vein. This is a considerable expense, but still in the end the most economical mode of getting rid of the water, which must otherwise be raised by pumping, an operation which must still be resorted to in regard to that part of the mine which is below the upper part of the adit. Some of these adits are of great length; the adit into which the steam engine of Chacewater mine pumps its water is not less than 24 miles long; it is the deepest adit in the county, and flows into one of the creeks of Falmouth Haven.

As soon as the vertical opening, or shaft, is sunk to some depth, a whim is erected to bring up the deads and ore in baskets, called kibbuls, one of which goes down empty while another comes up full. The whims are turned by two horses, and it is estimated that these horses save to the county the labour of 10,000 men. As the lode never runs down perpendicularly it is necessary to cut galleries, called levels, generally about two feet wide, and six high, in a horizontal direction. Other shafts are also sunk which traverse the several levels, or a special communication is made between only two galleries by a particular shaft called a winz. When several levels run parallel to each other through the rock, or country as it is called, they are made to communicate by other levels, called cross cuts.

For keeping the workings from being inundated, each mine is furnished with a chain of pumps, descending from the adit level to the bottom of the mine, or sump, as it is called, all these pumps are worked by a single pump rod, moved by steam engines: whose aggregate power is supposed to be at least equivalent to the labour of 40,000 men. The water is raised by these pumps, each of which receives the water brought up by the one immediately below it, until it reaches the adit, through which it flows by a gentle descent to the surface.

Fig. 130 represents the section of a continental mine, which differs in some slight respect from our Cornish mines.

*A*, is the drum of the whim used for drawing up the ores, by means of the buckets, *b*, which are attached to it by ropes or chains, one bucket going down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is the other comes up. The horses which turn these drums are trained to stop at a signal given to them, and to turn back and move in a contrary direction. The ropes move over the pulleys, *c*, and are thus brought over the well or shaft of the mine.

As it is sometimes necessary to stop the descent of the bucket instantaneously, an apparatus called a bridle is used. Two long beams, *d*, *e*, are placed one on each side of the drum, *a*; each has attached to it a concave log that closely embraces the convex surface of the drum, *a*. These beams are brought, when necessary, close to the drum by means of the two iron rods, *f*, which are fastened to the cylinder, *g*. The cylinder itself is turned by the rods, *h*, *i*; and thus a labourer, by means of the lever, *k*, which moves the vertical rod, *i*, is able to bring the beams, *d*, *e*, close to the drum, and stop its motion, in spite of all the efforts of the horses, or the weight of the descending load.

*L*, represents the plan of the mouth of the mine, which is divided by boarded partitions into two and sometimes three divisions. In the first, *l*, is placed the pump, the perpendicular ladder by which the miners descend, and sometimes pipes for forcing fresh air into the mine, or extracting foul air from it by machinery. The other two divisions are for the buckets; if they are not actually divided by boards, great care is necessary to prevent the sway of the buckets from entangling the ropes. *M*, is the bucket division of the shaft, here represented perpendicularly, which is the common direction, but in some mines the shaft is inclined. Each method has its advantages. The inclined shaft is generally carried on in the vein itself, so that the ore extracted is to be placed against the cost of making the shaft; and, as the buckets are made to run on rail ways, and the weight is supported by the wheels, the friction is not very great. *N*, is another shaft at a distance, with a ladder, being only intended as a passage into a distant part of the mine, and for ventilation.

It is to be observed, that the drawing of the galleries, and their distance from each other, are not in proportion to each other, for want of room in the plate.

*O*, is one of the principal galleries, leading to the main shaft of the mine; *p*, is a gutter or drain, running along the gallery, and leading to the well, or sump, *q*. *R*, are cross galleries, by which the main galleries are connected, or the miners search for ore.

In working a vein *under foot*, a scaffold, *s*, is let down three or four feet below the floor of the cross gallery, *r*, and as many miners as can work side by side, descend upon it, and cut out two parallelopipedons, 1′, 2′, about three feet high, and six or eight yards long. As soon as the miners are arrived at 3′, more miners are set to work, but on a lower level, *t*. These cut out the second step, while the first set work on the upper level. As soon as these miners have cut out the second step, 2, a third gang is set to work on a still lower level, and thus a kind of stairs is formed, on which a great number of the miners may work at once, without incommoding one another, and as the ore has always two of its faces free, it is the easier to cut or blast.

In this method of working, there is a necessity to support the roof of the vein; and if, as is commonly the case in the continental mines, the vein stones or deads are not brought up to-day, but left in the mine, there is an equal necessity to find some place for them. For these purposes strong scaffolding is constructed behind the miners as fast as they proceed in their work, and the dressers of the ore throw the rubbish on these scaffolds, where it is left.

In working a mine *over head*, a miner at the bottom of the shaft, *m*, cuts out a parallelopipedon, 1′, about five feet high, and six or eight yards long. When this is achieved, another miner is placed behind him, and the first proceeds forward, to 2′, 3′, 4′, the second miner brings down the ore from a higher level, 2, a third from a still higher level, 3, and so on, until the vein is exhausted.

Each of these methods have their respective advantages. In working a mine under foot, the miner stands on his work; he cuts straight before him, without any inconvenience, and is not exposed to the ore falling upon him. As the way by which he entered the vein is shut up by the rubbish thrown behind him, he gets out by the bottom of the stairs he forms, and it is also by this passage that

the ore is carried out. On the other hand, it requires a considerable quantity of large timber to construct the scaffolding.

In working over head, the miner is more fatigued, and as the ore falls on the rubbish on which the miner stands, some of the ore is lost amongst this rubbish.

The pumps for extracting the water from our English mines, are usually worked by steam engines; but in Hungary, and the east of Germany, they are worked by a column of water, as expending less water than a mill wheel, and therefore more economical, even if a stream to turn a thirty feet wheel, and a fall of twenty fathoms or more, can be obtained. These machines were first brought into use by Hoell, in the Schemnitz mines, about 1749, and their use has gradually spread westward, and it is in consideration, to employ them in the Hartz and Saxon mines. Their construction, being merely mechanical, does not belong to this work.

## *Mechanical Preparation of Metallic Ores.*

After the ore has been dressed, by knocking off, by means of hammers, the vein-stone adherent to it, a farther preparation is necessary to fit it for fusion; the machinery for this purpose is brought to great perfection in Germany, although Humboldt allows that the Spaniards in America prepare their ore still finer than the Germans.

Fig. 131, represents a paddle wheel for washing ores. *A*, is a water mill wheel, turning the arbor, *b*. *C*, is a hollow trunk into which the ore is thrown. *D*, a trough by which a stream of water is made to run into the trunk, *c*. *E*, are bars of iron that form the paddles by which the ore in the trough is moved about, that the stream may wash off the adherent clayey or earthy matters. *F*, a trap which is opened occasionally to allow the ore when it is sufficiently washed to fall into the canal, *g*. through which the water forces it into the cistern *h*.

Fig. 132, is a section of a stamping mill, for reducing ores to powder; as they are generally very hard, the bottom of the mortar is composed of a bed of the ore itself. *A*, is one of the pestles, or stampers, of which there are usually from six to fifteen in the same trough or mortar. *B*, is a groove in the stamper, in which the wipers, *c*, work, in order that it may be raised perpendicularly. *D*, are friction rollers, to facilitate the motion of the stamper. *E*, the lower end of the stamper, armed with iron. *F*, the arbor of the mill wheel, furnished with the wipers, *c*. *G*, is the trough of the stamping mill, or mortar, *h*, that part of the trough in which the ore being stamped is lodged. *I*, is the trough by which a stream of water is made to run into the stamping trough. *K*, is the trough by which the water runs off, carrying with it such of the ore as is stamped sufficiently to pass an upright screen into the trough, *l*, from whence it is carried by the stream to the shaking tables, or elsewhere.

*M*, is a chest, or hopper, into which the dressed ore is flung, and from whence it descends by a hole in its bottom, along the inclined plane, or slide, *n*, into the stamping trough.

Bucket sieves are sometimes employed, in which a labourer can sift rich ores in a tub of water. A lever, from whence the bucket is suspended by an iron rod, and a counterpoise to the bucket and ore is used, in order that the labourer may easier raise the bucket by means of a handle, and place it on the table. This mode of preparing ore is only used when the ore is very rich and water extremely scarce.

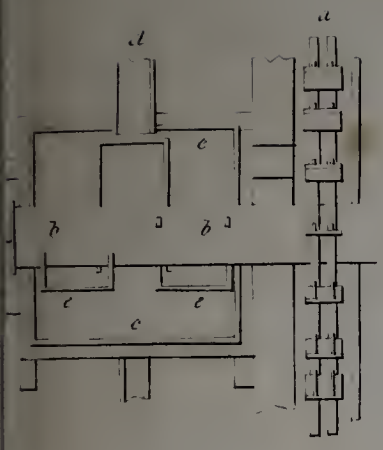
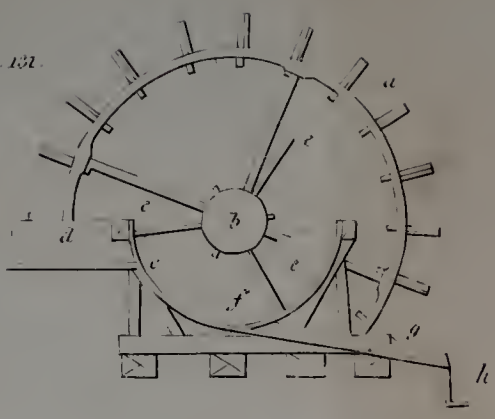



Fig. 131.



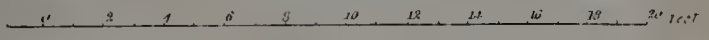



Fig. 132.

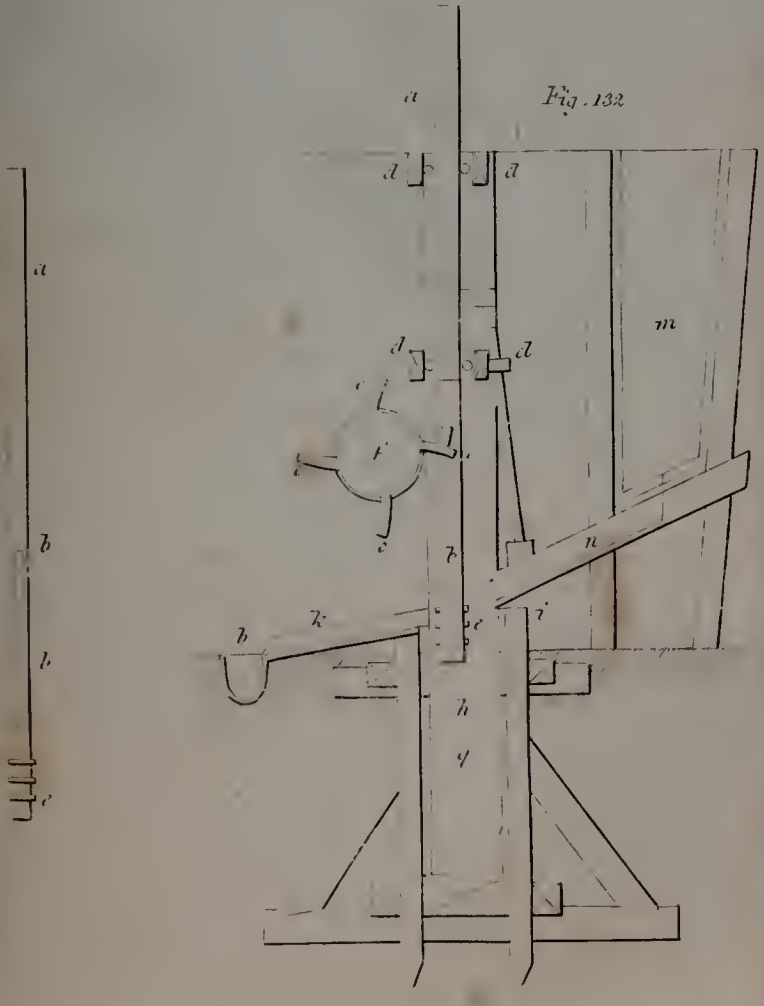
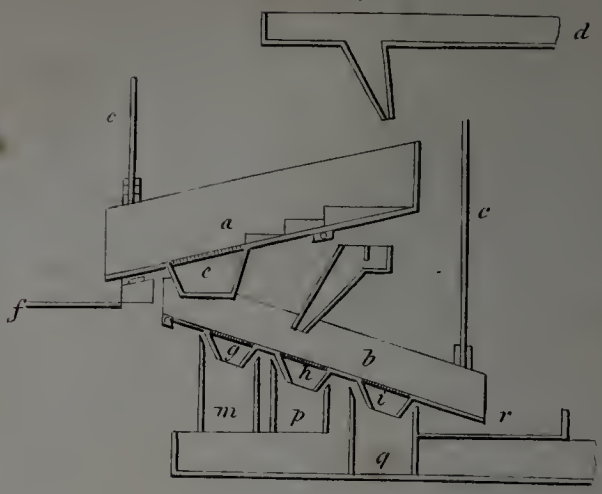


Fig. 133



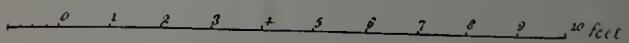




Fig. 134

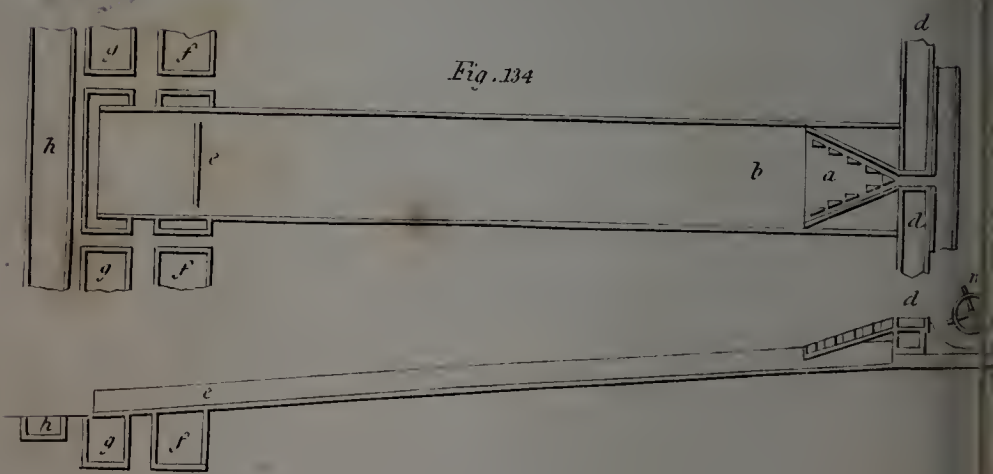
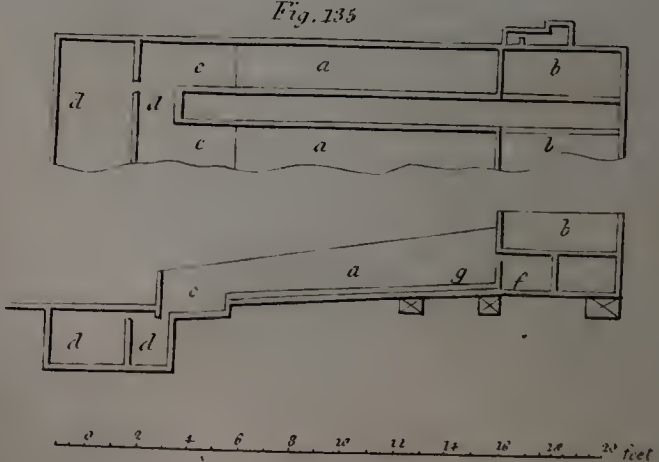
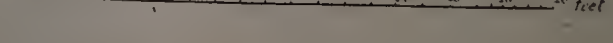



Fig. 135



Another kind of sifting machine is sometimes used in the Saxon and Hartz mines when water is scarce. A slide is generally used, down which the smaller pieces of dressed ore are flung from the mouth of the mine, when situated higher up a hill. By pulling down the upright stem, the trap of the slide is opened, and the ore falls into a chest, the bottom of which is formed of a grating; and it then immediately falls into the water of the cistern.

The chest moves on a horizontal axis, sliding between two upright beams. The workman having shaken the chest in the water of the cistern, raises it by means of the handle, and having stopped its falling by putting in a block of wood, shoots the ore, by means of a lever opening a small trap in the side of the chest, upon the table where the dressers work.

The smaller grains of the ore which pass the grating of the chest, settle in the water of the cistern, from whence, by opening a plug in its bottom, they are conveyed, by the water rushing out, into other machines, where they are farther prepared.

Fig. 133, represents a turning over screen, used in the Hartz mines, principally for the screening of lead ore holding silver. *A*, *b*, are two narrow chests, the lower end of each of which is connected by an iron rod, *c*, with the arm of a small lever, which is moved up and down by wipers placed on the arbor of a mill wheel. By this means the lower ends of the chests, *a*, *b*, are raised and let fall alternately. *D*, is a trough by which a stream of water is led to the chests, to assist in the screening of the ore. The ore to be screened being broken small is flung on the upper part of the chest, *a*, and a stream of water directed upon it; the ore which cannot pass the coarse screen or cast iron grating, *e*, slides along to the table, *f*, where it is examined by the dressers, and separated by hand, either to be stamped, dry or wet, or thrown amongst the rubbish, or for immediate smelting. As to the ore that passes the coarse screen, *e*, it is carried by the water over the two brass wire sieves, *g*, *h*, and an iron wire sieve, *i*, which form the bottom of the chest, *b*. The ore that passes through the sieve, *g*, is called fine sand, and is collected in *m*; that which passes through the sieve, *h*, coarse sand, and is collected in *p*; both of these sands are afterwards washed upon the washing tables. The very coarse sand that passes through *i*, into *q*, is washed in a bucket sieve; as is also the large pieces that will not pass through any of the sieves of the chest, *b*, and is collected in the chest, *r*. This apparatus is very simple, and useful in separating ore into different finenesses.

Fig. 134, represents a fixed washing table, called a sweeping table, used in the Hartz mines, for separating the clean ore ready for the furnace from the other ore. Two or more of these tables are usually placed side by side in a washing house. The stamped or screened ore is brought by the trough, *c*, and to hinder it from settling, the water is continually agitated by the small paddle wheel *m*; from this trough it flows with the water over the triangular space, *a*, and is spread by means of the stops on the sides of this space equally over the table, *b*, *e*; a stream of clear water being also brought by means of the trough, *d*. Towards the bottom of the table is a slit, *e*, which is kept close during the flowing of the water, which carries off the earthy matter into the trough, *h*. When the table is filled with ore, that below, *c*, is swept into the cistern, *g*, and the slit, *e*, being opened, the ore on the upper part of the table, is swept through the slit into the cistern, *f*.

Fig. 135, represents a simple fixed washing table, for the preparation of ore which is too fine for the screen, and yet too large for the sweeping, or moving washing tables. The chests, *a*, or tombs as they are called, are about three yards long, twenty inches wide, and their sides of the same height; their bottom lies on a gentle slope. At the upper part is a kind of flat ledge, *b*, on which the ore to be washed is placed, and under this ledge is a trough, *f*, by which a stream of water is let over the table and runs off through holes in the end boards of the chest, *a*.

The workman throws a parcel of ore upon the raised ledge, *b*, at the upper end of one of the three tables that constitute a set, and letting on the water and keeping it at different heights, by stopping or unstopping the holes in the

end boards, he transfers the ore as it settles in different parts of the first table into the second, and from thence to the third, and thus obtains clean ore of different qualities and sizes by a single operation, according to his skill in washing; while the still finer particles are carried off by the water, into the troughs, *d*, which are continued to a great length, with many turns and returns, so as to be kept in a small compass and of different widths; the broader troughs having stops put half way across them, in order that the ore may be thoroughly separated into different parcels according to its various specific gravities.

Fig. 136, represents a longitudinal section, in the direction, *y*, *y*. Fig. 138, of another kind of washing tables, which are moveable, and called shaking tables. Fig. 137, is the transverse section, in the direction, *x*, *x*; fig. 138, of the same; and fig. 138, the plan.

The table, *a*, is about four yards long, and five feet broad; the edge and end boards rise about eight inches. This table is not fixed, but hangs by means of four chains, one at each corner, *b*; when the table stands still it hangs inclining towards the feet.

Above and behind the table is a fixed platform, *c*, which supports a triangular inclined plane, *d*, with boards on the sides, and several blocks of wood, *e*, which serve to divide the stream of water and spread it equally over the table. Above this inclined plane, *d*, is fixed the chest, or hopper, *e*, into which the screened ore is thrown. The bottom of this chest slopes, and is separated into two parts by a sluice, *f*, which has a hole, *g*, in its bottom part. The screened ore is thrown into the upper division, *h*, the lower division, *i*, remaining empty. A trough, *k*, passes over these tables and brings a stream of water, which flows through the two pipes, *l*, by one of them being directed into the filled division, *h*, and by the other into the empty division, *i*. The ore is carried by the stream into the empty division, and from thence is spread evenly over the table, and would be carried by degrees off the table; but while this is going on, the head of the table receives a stroke from the machinery, *m*, which pulls it forwards, and this stroke being intermitted, the table returns to its former station, receiving, however, in striking against the block, *n*, a violent shock.

The machinery, *m*, that produces this motion of the table, is composed of an arbor, *o*, furnished with wipers, *p*. These wipers lay hold of the end of the lever, *q*, by which the roller, *r*, is turned round a little; the end of the lever, *s*, is brought forward, and consequently the horizontal beam, *t*; this beam being thus moved, is driven against the head of the table, *a*, and as the table returns to its place it strikes against the block, *n*.

The object of this motion and shaking of the table is, first, to separate the stony particles that had adhered to the ore, by communicating to them unequal velocities, in proportion to their different specific gravities; and, secondly, to bring the particles of the ore, as being the heaviest, towards the head of the table.

In washing different kinds of ores on these tables, attention must be paid to several circumstances. The table is hung at different slopes, from one to seven inches. The water is also let on, sometimes in a very slender stream, and sometimes very flush, to the amount of two cubic feet by the minute. The number also of shocks given to the table varies from fifteen to thirty-six in a minute; and it is pushed from its original hanging from an inch to six inches, by which the shock itself is varied in its strength. The screened ore, called gross sand, requires, in general, less water and a less slope than the fine or clammy sand.

When it is ascertained that the ore is completely washed, and that the water that runs off contains none of the ore, the water is allowed to pass on along the trough, *k*, while the clean ore is taken out; but if there is a suspicion that the water still contains some particles of the ore, the trough is stopped, and the water is allowed to run off into a trough at the foot of the table, where it deposites those particles which are again submitted to the process of washing.

By the skilful combination of these means of stamping and washing ores, as practised in the German mines, very poor ores

Pl. 43

Fig. 137

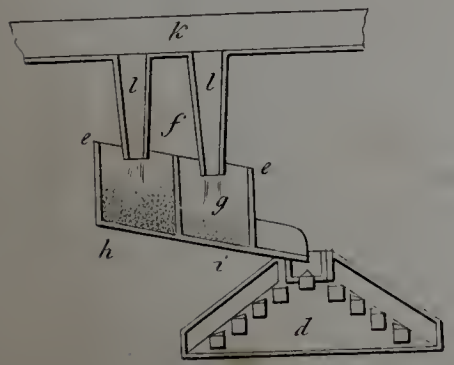



Fig. 136

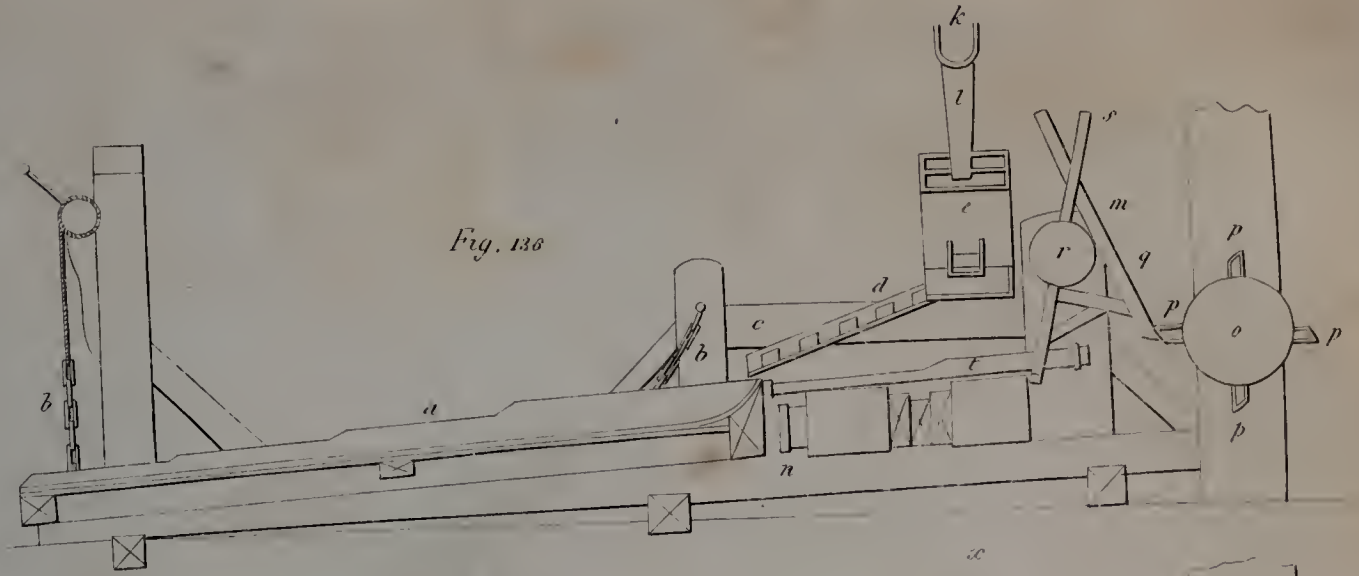
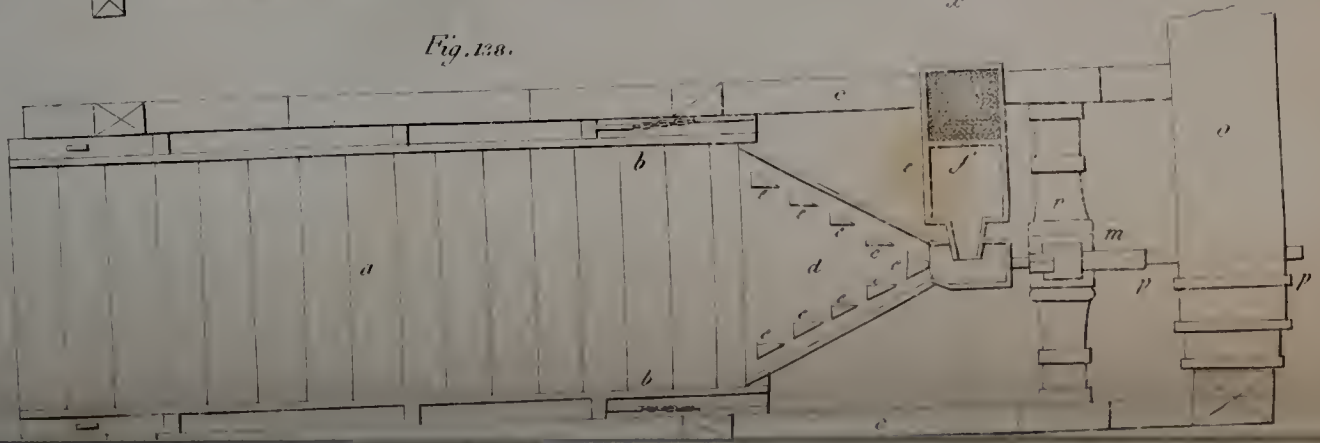



Fig. 138.



are rendered profitable, such as those of the two mines of Frankenscharn and Altenau, in the Hartz, which raise annually 876,200 cwt. of ore. This, by stamping and washing, is reduced to 111,367 cwt. of clean ore, sorted into four qualities; and these by smelting yield 35,582 cwt. of lead, or its equivalent of litharge, 84 cwt. 7 of silver, and 49 cwt. 1 of copper.

For washing on a small scale, the chemist should be provided with a trough, about a foot long, an inch and a half broad at one end, and three inches at the other, where it should be three quarters of an inch deep. The clay, sand, pounded ore, or dirt, is mixed with about four times its quantity of water, the trough kept very loose between two fingers of the left hand, and some light strokes given on its broad end with the right; by which means the heaviest particles are brought to that end, and the lightest may be separated by inclining the trough and pouring a little water on them.

### *Chemical Preparation of Ores.*

There is another preparation which most ores undergo before they are smelted, in order to get rid of the volatile substances, which by uniting with the metal would render it impure; these volatile substances are generally sulphur or arsenic. As this preparation consists in exposing them to a gentle and long-continued heat, it is called roasting of the ores.

Some minerals are roasted only once; others, particularly copper ores, a number of times, even fourteen or more. These repeated roastings are rendered more effective than a single long-continued roasting by melting the ore between the roastings in order to distribute the volatile substances equally throughout the mass.

Some ores, as copper pyrites, bituminous copper ore, and the like, are roasted in immense uncovered heaps.

Fig. 139, represents an uncovered heap of this sort, some of which are composed of several hundred tons of ore. The bottom of the heap, *a*, *b*, is formed of two or more layers of fuel, the rest being only ore. The largest pieces of ore are thrown towards the hollow space, *c*, *d*, which is left partly as a chimney, and partly to light the fire, by throwing down some lighted fuel, and the smallest pieces towards the surface of the heap, which is sometimes beaten close together, and sometimes covered with earth, *e*. The fuel being lighted, the roasting is continued by the sulphur or bitumen for a long time, sometimes for years together, fresh ore being supplied at one end of the heap, and that at the other carried away. Care is usually taken to stop any cracks that may happen at the sides, and oblige the vapours to pass out at the top only of the pile. Holes are frequently left at the top, in which a part of the sulphur is collected, and removed before that part becomes so hot as to dissipate it. When the ore is very combustible little or no fuel is necessary, and the heap is lighted at top. In some cases these heaps are placed under sheds, to hinder the rain or wind from extinguishing the fire.

Fig. 140 represents a section, and fig. 141, a plan, of a plain kiln, for roasting ores, which is generally made of a small size, the place for the ore being about eight feet from side to side, six from front to back, and four deep, surrounded by walls, *a*, the floor slopes down from the back to the front, and is covered with a layer of fuel, upon which the ore is thrown. When the furnace is full, as the air is admitted at *c*, in the front wall, the ore is covered at top with fine stamped ore, *d*, to force the sulphur to pass through the openings, *e*, in the back wall, into the room, *f*, where the sulphur fixes, and the incoercible vapours pass off by the chimney. In the lower Hartz, a kiln of this kind, containing about 2000 cwt. of ore, and 730 cubic feet of wood, will in four months produce 30 cwt. of sulphur.

Fig. 142, represents a plan of part of a row of roasting kilns, which consist only of a back and side walls, but are open to the front; and fig. 143, is a section of the same. These kilns are usually built in opposite rows under a shed; the fuel is laid at bottom, the coarse ore thrown upon it, and covered with fine ore; by which the vapourized sulphur is forced through the opening, *c*, in the back wall, *d*, and condensed in rooms similar to those represented in fig. 140, and 141.

When the ore contains a less proportion of sulphur or bitumen, and of consequence will not maintain the heat of the pile; as also when the ore is stamped fine, and will not allow the passage of air through it, then a proper furnace must be erected for the purpose, with a distinct room for the fire.

Fig. 144, represents a vertical section of a reverberatory furnace used in Germany for roasting such kinds of ore; fig. 145, is a horizontal section of the upper part, on the level of the floor of the condensing rooms, *e*, and fig. 146, is another horizontal section on a lower level, just above that of the grate of the fire room, *a*.

*A*, the grate on which the fuel is burned, the flame of which traverses the roasting rooms, *b*, and *c*, and passing up the pipe *d*, it goes through the condensing rooms, *e;* the smoke and vapours escape by the chimney, *f*. A space, *m*, is left between the main body of the furnace, and its external wall, which serves partly as a receptacle for the roasted ore when drawn hot out of the furnace, and partly to prevent the spreading of the vapours, which are carried off by the hood, *n*. *O*, are openings in the bed of the furnace to breathe out the moisture when first built.

The ore to be roasted is first placed on the roof, *g*, of the condensing rooms, *e*, where it is dried by the heat, and then shovelled down the hopper, *h*, into the upper roasting room, *c*, after which the hopper is closed, and the ore is spread evenly over the floor of the room, *c*, by a rake, introduced at the opening, *i*. Here it remains one or two hours, and is gradually heated, and is then pushed by the rake upon the floor of the lower roasting room, or altar, as it is called, where it generally begins to burn, and requires but little fuel in the fire room. Afterwards the fire must be increased to volatilize the last portions of sulphur and arsenic which remain; when the roasting is finished the ore is drawn out by the doors, *k*. The operation usually lasts twenty-four hours.

The greatest part of the sulphur and arsenic in the ore is condensed in the rooms, *e*, from whence it is taken out occasionally by the workmen entering at the doors, *l*.

In some of these furnaces a drying room for the ore is placed between the roasting room, *b*, *c*, and the condensing rooms, *e*, which form the third story of the furnace, as at Lautenberg; this construction has the double advantage of exposing the wet ore to a greater heat, by allowing the heat to enter from the fire by two or more wide mouth hoppers, always open; and of the condensing rooms being cooler, as heated farther from the fire.

Fig. 139

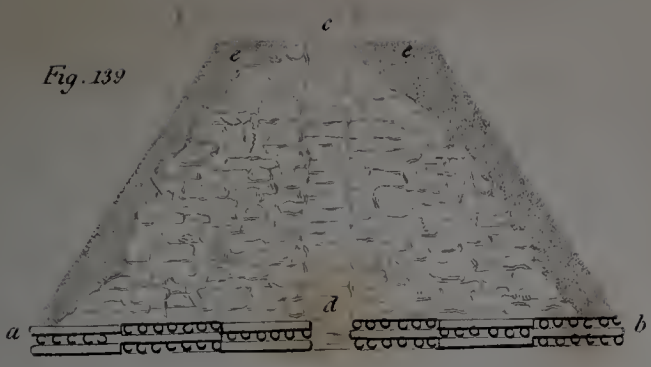



Fig. 140

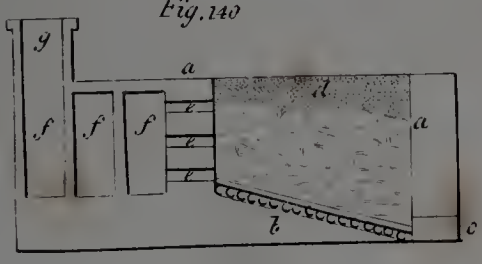
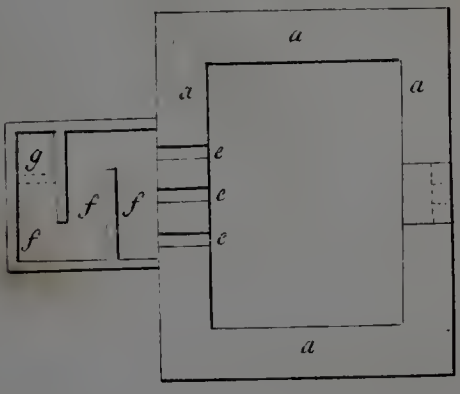



Fig. 141



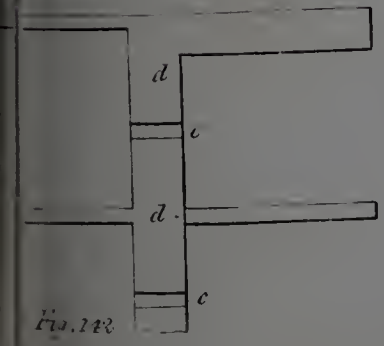




Fig. 142

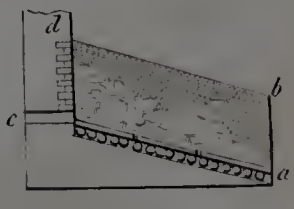



Fig. 143

0 2 4 6 8 10 12 14 16 18 20 feet

Fig 144.

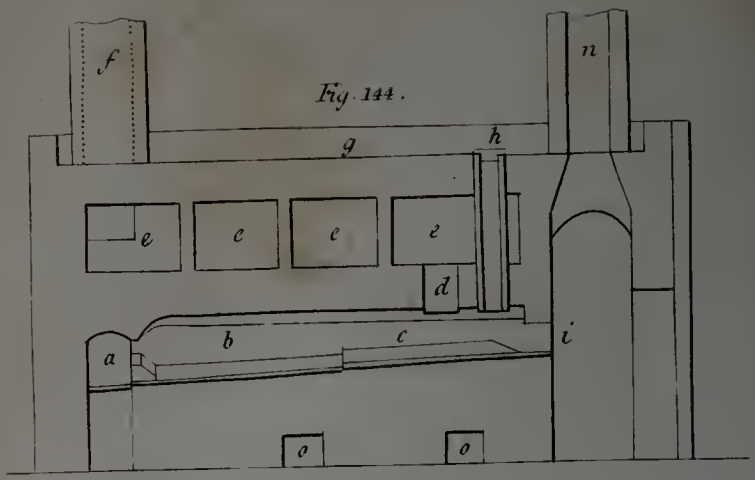



Fig 145

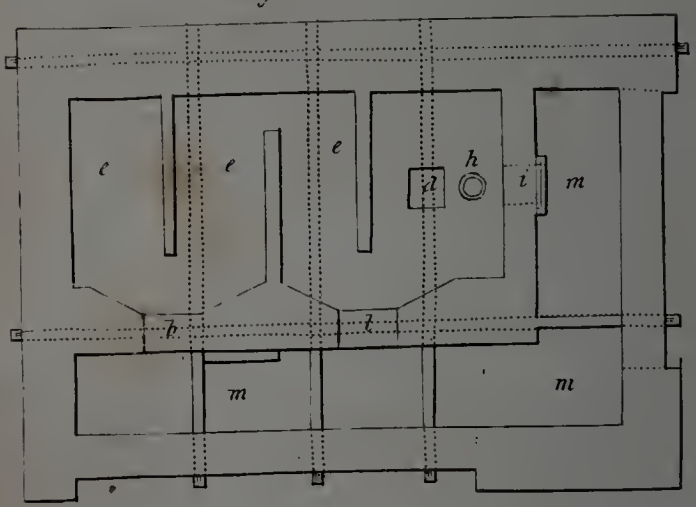
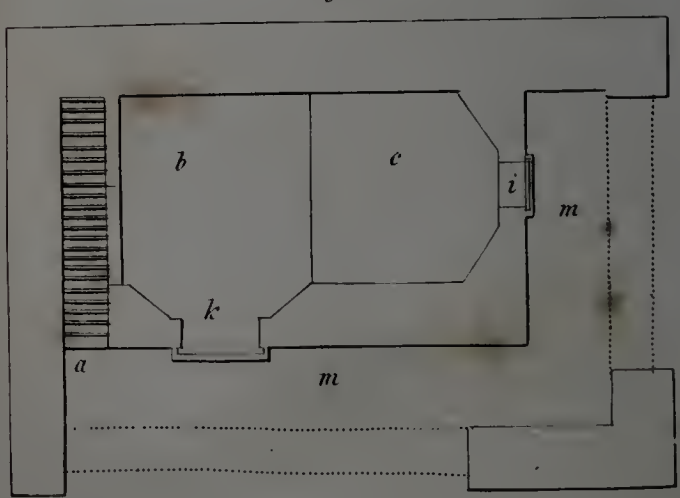



Fig 146



## *Blowing Machines.*

The prepared ore is smelted either in blast or draught furnaces; the blast furnaces vary in height, and are distinguished into high or low furnaces; the draught furnaces are generally of the reverberatory kind, but attempts have been made of smelting iron ores in air furnaces, surmounted by a very high chimney, to cause a sufficient draught without the use of blowing engines, the fuel and ore being thrown into the very deep fire room alternately.

The blast of a fall of water, and that of bellows moved by machinery are frequently used even in the largest metallurgic establishments; but lately there has been substituted for these blowing machines the action of pistons, moving in large cast-iron cylinders, or that of a bell alternately raised or depressed in water.

Fig. 147, represents the section of a blowing machine of the first kind, with a regulating cistern. This machine of two cylinders of cast iron, in each of which a piston, *p*, furnished with leathers, *v*, is made to move by the action of an arbor, *a*, turned by a water wheel, instead of which agent the crank of a steam engine is usually employed in England.

*B*, is an elbow crank, which moves the rod *b*, *c*, that by means of the crank, *d*, communicates motion to the bent iron axis, *d*, *f*; *i*, are the piston rods, jointed in the middle, and running in the grooves, *k*, by which means an upright action is produced. The cylinder, 1, is represented as filling with air by the piston being drawn up; in consequence of which motion the valves, *s*, in the bottom of the cylinder communicating with the air vault, *c*, under the frame work of the machine, are raised by the pressure of the atmosphere to admit the air into the cylinder, 1, and the valve, *t*, through which the air enters into the blast pipe, 3, is shut by its own weight. The cylinder, 2, is shown as descending and forcing out the air through the valve, *t*, of course the inspiring valves, *s*, are shut, having fallen by their own weight.

This machine appears at first sight very simple and efficacious, but it has its inconveniences: 1, the blast is unequal, being sometimes stronger than at other times: 2, the friction of the pistons is very considerable.

The first inconvenience is remedied by one or other of the three methods already pointed out in p. 59; the third method is represented in the figure, as being adopted with the machine as there drawn.

5, is a large bell, of wood or iron, constructed in a deep cistern of water, *q*, so as to be immoveable. The cistern is filled with water up to the level, *n*, when the machine is not at work; but when it begins to work, the level within the bell is depressed, and that in the cistern raised to the levels, *m*, by the blast of air that rushes from the cylinders through the blast pipe, 3, into the bell, 5. The difference of this level, *m*, from that of *n*, is shown by the gauge, *l*, *m*, composed of a hollow copper floating ball, and an iron stem, with an index at the top, pointing to a graduated scale on the frame work; and measures the force of the blast, which is thus equalized, and conveyed by the second pipe, 4, to the furnace itself.

By this means the blast is indeed equalized, but the friction of the pistons cannot be got rid of.

Fig. 148, represents the floating bell, or hydraulic blowing machine. *A*, is a wooden or cast-iron bell, which is raised and lowered by the rod, *b*, connected with some moving power, as a steam engine or water wheel, *C*, is a cistern of water in which the bell is suspended, and moves up and down. *D*, is a valve which opens by the pressure of the atmosphere, and allows the air to enter and fill the bell as it is raised up by the moving power, which is the state in which it is represented in the drawing. *E*, is the first portion of the blast pipe, by which the air is forced on the descent of the bell, and the consequent falling down of the valve, *d*, into a regulating cylinder, as figured in fig. 147, No. 5. *F*, is the valve or trap, which prevents the return of the blast into the bell, as it rises. *G*, are rollers, to guide the bell as it moves up and down, and preserve its perpendicularity.

The blast from these machines, as well as that from bellows or other contrivances, is generally directed into the fire itself; but in some cases it is also applied to the substances submitted to the action of the fire; and in others it is not applied to the fire, but only to the substances which are being worked, as in refining copper and silver.

As the air is saturated with water in the bell of the regulating cistern and in the floating bell, the moisture is prejudicial in some cases: hence their use has been abandoned, and the blast from the pistons thrown directly into the furnace.

## LEAD.

Lead is the most common of the metals, and is usually combined naturally with sulphur, which is got rid of by various operations.

*Raw lead*, is that obtained in the smelting works, which is impure, and requires refining for sale.

*Saleable new lead*, is that obtained in the smelting houses, and which does not contain a sufficient quantity of silver to render it profitable to extract that metal.

*Workable lead* contains sufficient silver to pay for its extraction.

*Refined lead*, is that reduced from the purest litharge, obtained in extracting silver; the litharge that contains much copper being rejected.

*Old lead* is obtained by melting old cisterns, lead roofs, and the like; it is rendered impure by the tin of the solder, and melts with a less heat than new lead.

In smelting of lead ores, a considerable difference occurs, some ores being run down for the lead only; which lead, if it contains sufficient silver to pay for the charges of extraction, is afterwards cupelled; the litharge blown off, and the purer

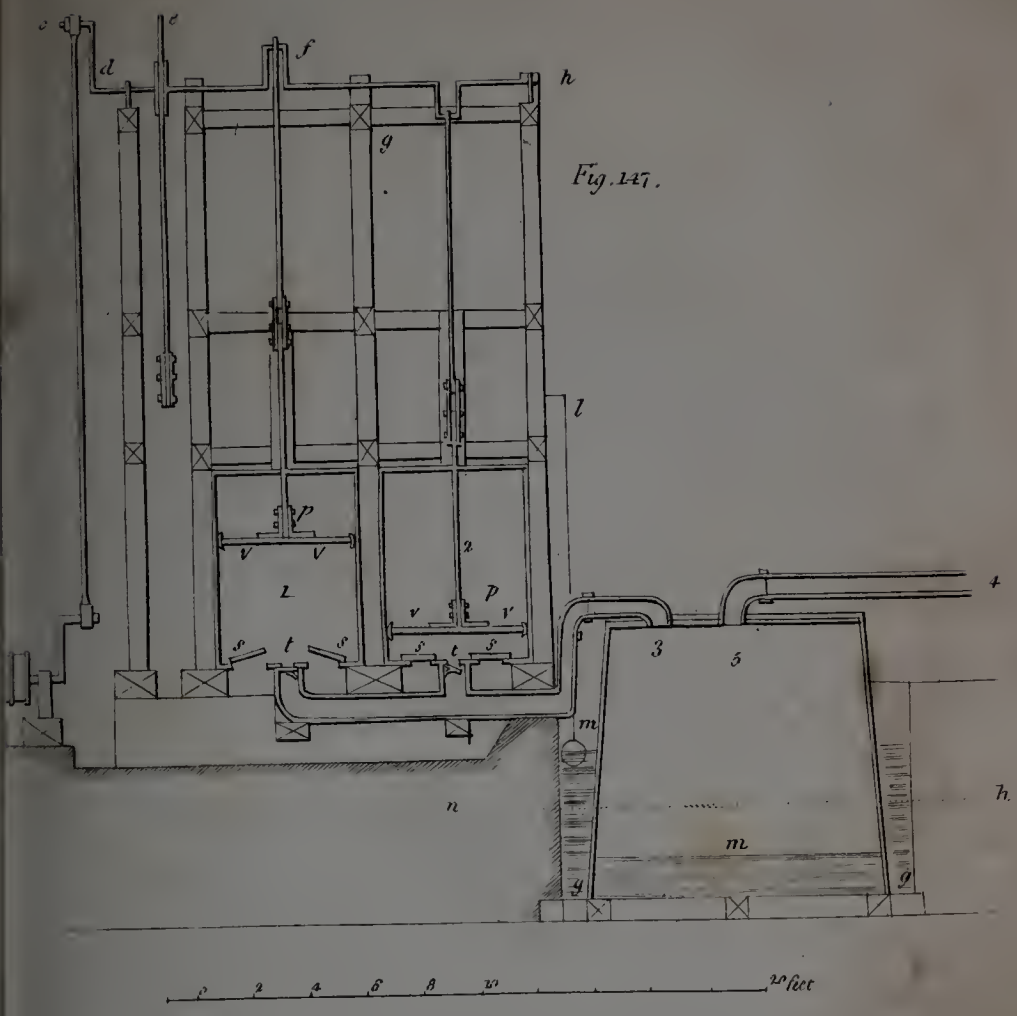



Fig. 147.

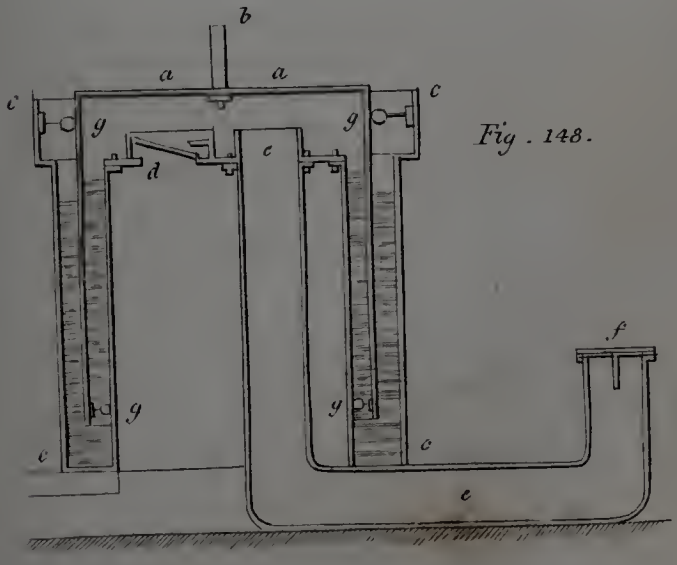



Fig. 148.

Fig. 149

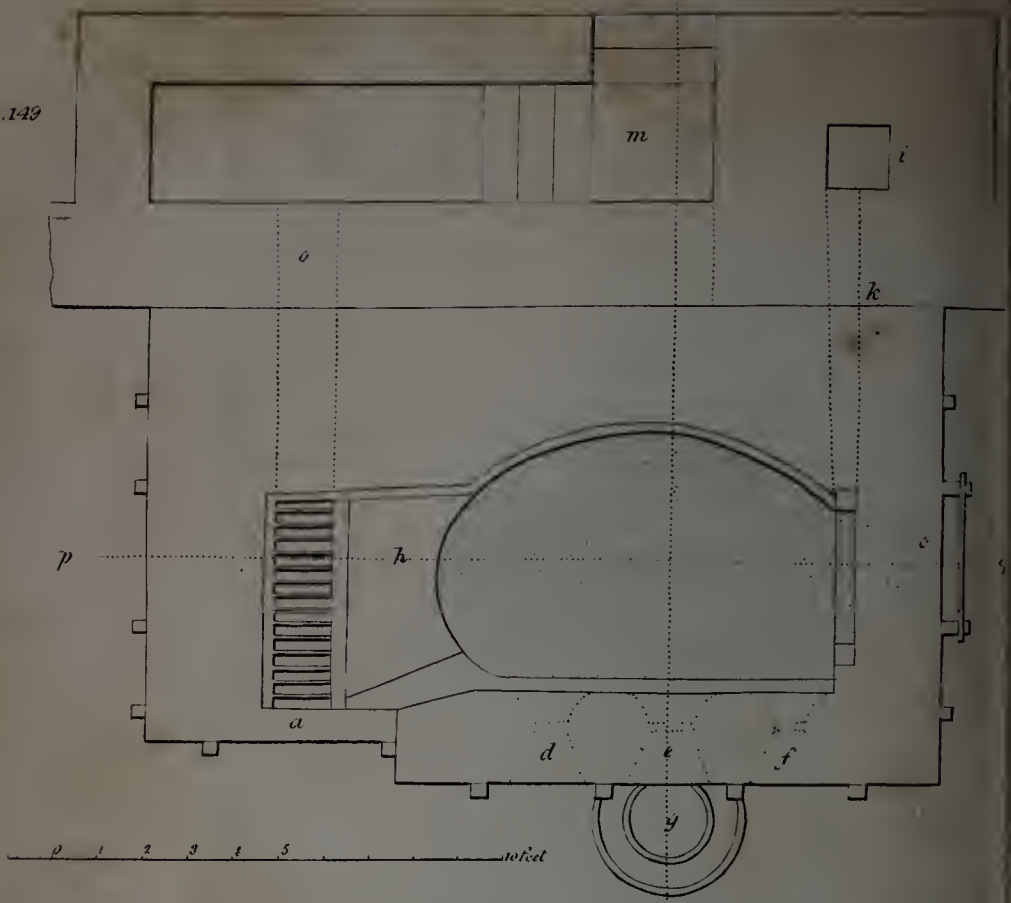
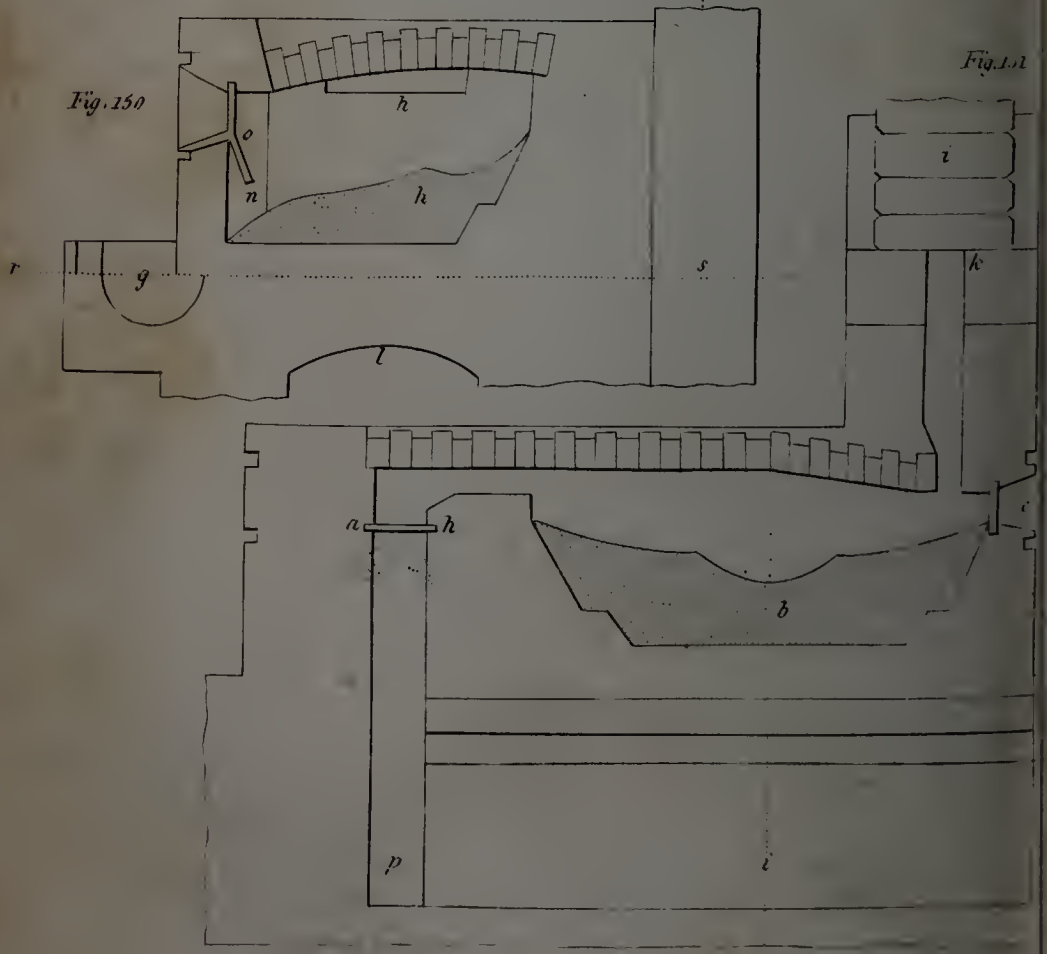



Fig. 150



arts reduced to lead. Other lead ores contain not only silver, but also copper, and these are subjected to a long train of processes to obtain each of these metals separately.

The smelting of the purest lead ores, is best performed in reverberatory furnaces.

Fig 149, represents the plan on the level, *r*, *s*, in fig. 150, and 151, of the reverberatory furnace used at Poullaouen, in France; which furnace is considered as the best construction hitherto adopted for these purposes. Fig. 150, the transverse vertical section, in the direction *g*, *m*, fig. 149, or *b*, *l*, fig. 151. Fig. 151, is the longitudinal vertical section, in the direction *p*, *q*, fig. 149.

*A*, is the fire room of the furnace, with its door and grate. *B*, is the bed, made of clay well beaten together. *C*, is the door by which the furnace is emptied. *D*, *e*, *f*, are three doors by which the furnace is charged, and the materials stirred; the middle door, *e*, is also that by which the smelted metal is run out of the furnace, into *g*, the basin prepared for its reception. *H*, is the bridge, over which the flame is directed and carried from the fire room, *a*, into the chimney *i*, *k*, which is about thirty-five feet high; the first part of the chimney or vent, *k*, lies inclining, and is covered with loose stones only; so that by taking up these stones, the sublimed matter deposited in this sloping channel may be extracted. *L*, is the vault under the bed of the furnace, to breathe out the moisture. *M*, are stairs by which the workmen descend to the fire room, *o*. *N*, is the hole, under the door, *e*, by which the lead runs out into the basin, *g*.

The ores smelted in this furnace are a mixture of the clean ore of Poullaouen, with that of Huel Goet. The Poullaouen ore contains 64 pounds of lead, and three quarters of an ounce of silver, in a cwt. of five score pounds; that of Huel Goet contains 59 pounds of lead, and two ounces and a quarter of silver; the mixed ore contains 61 pounds ·89 of lead, in a cwt.

Twenty-six cwt. of the mixed ore is spread on the bed of the furnace, and roasted for six hours by a fire of fagots and billets; the fire is then increased, charcoal is thrown upon the ore through the doors, *d*, and *f*, and the head melter stationed opposite, *e*, throws in quicklime, which is changed into sulphate of lime, and prevents the liquid metal from running out, until at the end of about an hour and a half; he pierces a hole, *n*, and the metal runs into the basin, *g*, where saw-dust and rosin are thrown on it to reduce any unmetallized particles that may have run out with it; the piercing of the wall of sulphate of lime is repeated every hour, so that eight or nine tappings take place in every smelting. The run metal is laded out of the basin, *g*, into moulds. When the operation is over, the slags are taken out of the furnace by the end door, *c*, and the bed repaired for a fresh charge.

The raw lead thus obtained, is cupelled in a cupola furnace.

The pure litharge obtained in this cupellation is smelted, 6 cwt. at a time, in a similar furnace, being kept in by a wall of quicklime, and is reduced by charcoal flung upon it; this produces sale lead, and some slags, which are reserved and smelted upon a bed of charcoal dust.

The slags, and broken up bed of the first smelting of the

ore, the litharge containing silver, the cupel scum, the broke up bed of the cupel, and the lead smoke taken out of the chir ney, are all mixed together and smelted in a low blast furnac this fusion produces a raw lead, often so impure that it must l smelted again on a bed of charcoal, and scummed, before it saleable; also slags, the cwt. of which contains about eig pounds of lead, a richer slag from the bottom of the upper b sin, and a black slag; all of which are mixed with the oth slags, and reduced in the blast furnace.

In all these operations, 100 cwt. of lead for sale requires t consumption of 2275 cubic feet of billet wood, mostly beec with some oak; 2435 cubic feet of brush wood and broom f gots; and 39 cwt. of oak and beech charcoal.

Fig. 152, represents a vertical section of the blast furnace used at Freybe in Saxony, for smelting a lead ore, containing copper and silver; and fig. 1 is the plan, at the level of *n*, *z*, in fig. 152.

*A*, *b*, is the level of the laboratory; *c*, *d*, *e*, gutters for carrying off the m ture disposed crosswise, and open to the air at *e*. *F*. is a bed of slags laid up the flags of gneiss that cover the gutters, *c*, *d*, *e*. *G*, *h*, and *i*, beds of r rammed clay, upon which is laid a bed of clay mixed with ground charcoal, *l*, *t*, forming the hearth of the furnace. *K*, *l*, is a hollow formed in this hea terminating in the receiving basin, *k*. *M*, is the fire-room of the furnace, ab eight feet high, open at the top. *N*, *z*, twyer or blast hole; by which, at Fr berg, the blast from two bellows is thrown into the furnace. *O*, are steps which the labourers mount to charge the furnace. *P*. is the mouth of the f nace, covered with an arch, *y*, on one side. *Q*, is the front wall of the f nace, under which the melted substances flow from *l*, to *k*. *R*, *u*, an ar supporting the steps, *o*, under which an inclined plane, *s*, is made, by wh the slags run off from the basin, *k*. *X*, is the lower basin, into which the le runs when the upper basin, *k*, is pierced.

The following suite of operations are carried on for smelting the lead o at Freyberg.

1. The working of the lead matt, or first fusion of a washed very poor s ver ore, to which is sometimes added some iron pyrites, if a sufficient porti does not accompany the ore. This matt is afterwards roasted. The ore ho only 1 loth (half ounce,) ·6 of silver, in a cwt. of 110 pounds.

2. The working of the lead, or smelting of a lead ore, yielding 28 or pounds of lead, 6 ounces of silver, and a very little copper, from a cwt. of t ore. The ore is previously washed, and roasted in a reverberatory furnac and smelted along with the roasted matt of No. 1, scum from the cupel a other products of cupellation, and any raw lead that is poor in silver. T products of this principal smelting are lead for the cupel, and a matt which roasted.

3. The smelting of the roasted lead matt, with other lead holding produc The products are a still richer lead for the cupel, and a copper matt, which sometimes smelted again before it is roasted.

4. Smelting of the copper matt of No. 3, to obtain black copper containi silver, which is afterwards refined.

All the above operations are performed in the furnace ju described; but the lead is cupelled in a cupola furnace, and t litharge run down, in a blast furnace.

This running down of litharge into refined or saleable lead, is a very simp operation; fig. 154, represents a longitudinal vertical section of the furnac

Fig. 153

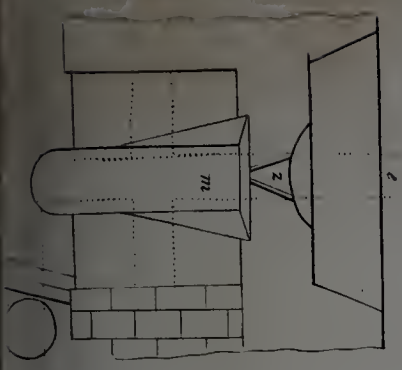
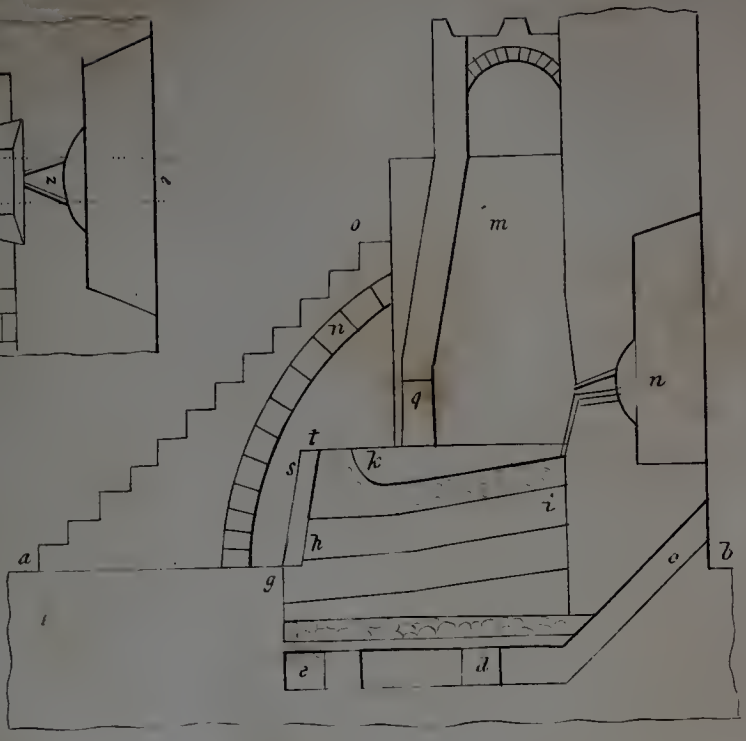



Fig. 152



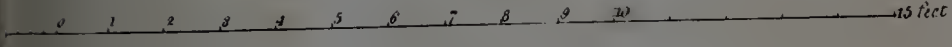




Fig. 154

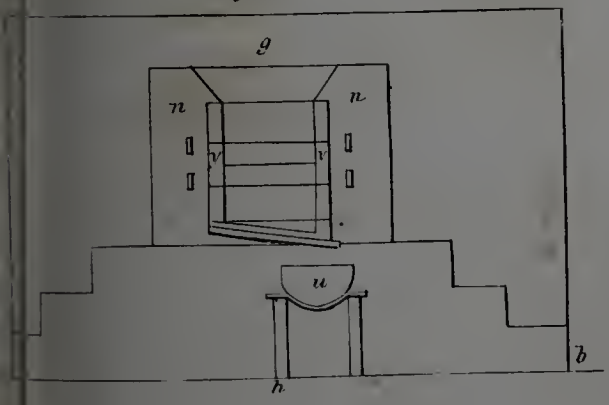



Fig. 156

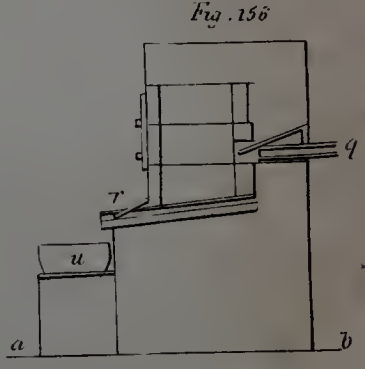
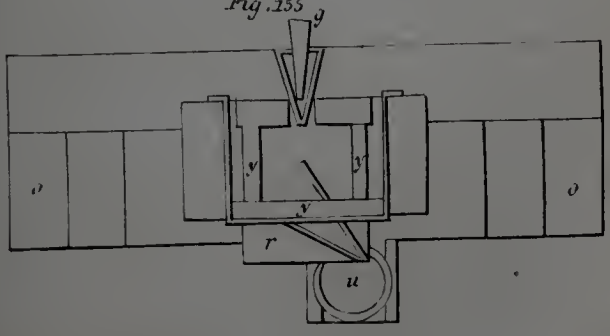



Fig. 155



Pl. 49.

Fig. 157

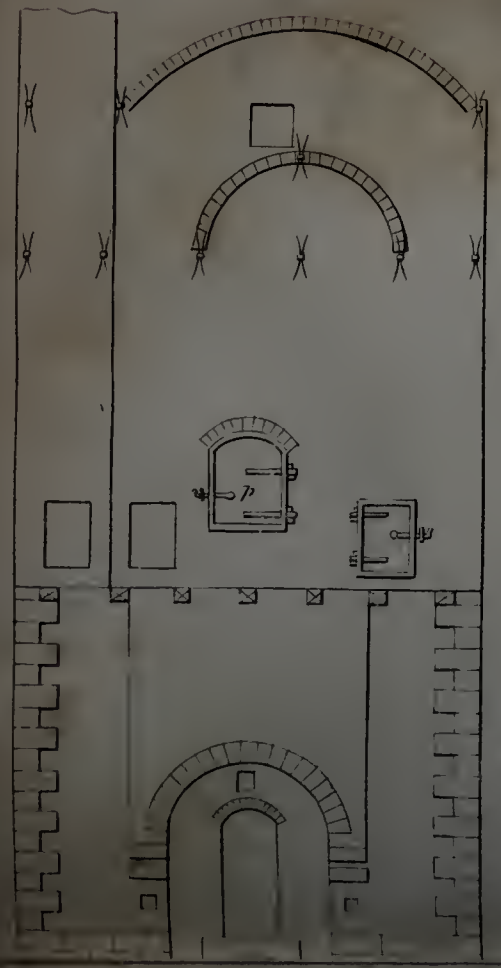



Fig. 158

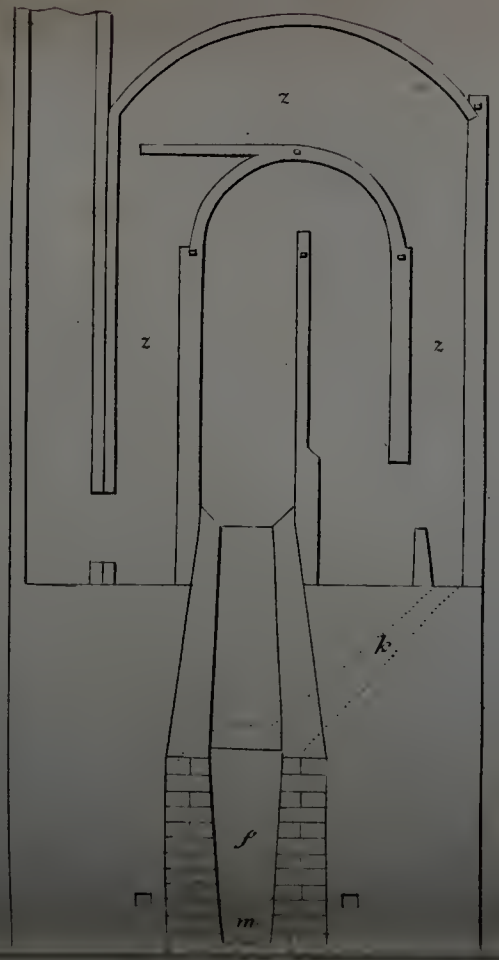



Fig. 161

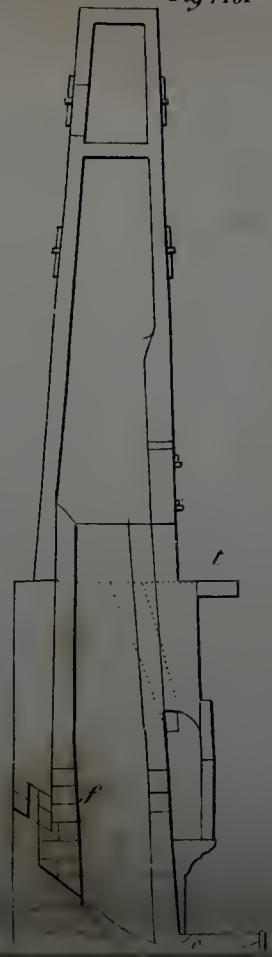



Fig. 159

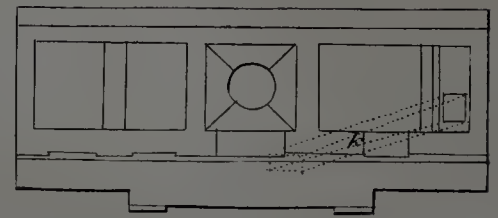
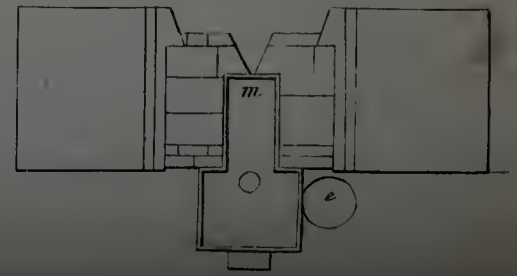



Fig. 160



usually employed for this purpose, on the line, *o*, *v*, in the plan, fig. 155, taken on the level of the twyer, and fig. 156, is a transverse vertical section on the line, *g*, *h*, in fig. 154, and *q*, *r*, in fig. 155. This furnace has also been used for smelting lead ore, and more advantageously than higher furnaces.

*A*, *b*, the level of the laboratory. *N*, the walls of the furnace, about two feet high, bound with iron bars worked in them. *Y*, slabs of cast-iron, forming the lining of three sides of the furnace. *Q*, is the twyer, by which the blast is admitted. *R*, a slab of cast-iron, placed on a slope, forming the bottom of the furnace; this slab has two grooves to favour and direct the running off of the metal. *O*, *v*, are the steps for the workmen to charge the furnace. *U*, a basin of cast-iron, placed on a stove, or in a pot furnace, to receive the metal as it runs from the furnace.

In some countries, much higher furnaces are employed for smelting lead ores, and instead of being open at top, they are enclosed, and furnished with a chimney or chambers; by which means the volatile substances are either preserved for sale, or prevented in some measure from affecting the neighbourhood.

Fig. 157, represents the elevations of a blast furnace of this kind, with a fire-room eighteen feet high, used at the principal lead mines of the Hartz.

Fig. 158, is a vertical section of the same, parallel to the front; fig. 159, a horizontal section on a level with the twyer; fig. 160, a horizontal section on a level with the mouth of the furnace; and fig. 161, a vertical section from front to back.

In all these figures, *a*, *b*, is the bottom bed of the furnace, with a double lining; the upper lining, *a*, being composed of two parts of clay, and one of ground charcoal; the lower, *b*, of one part of clay, and two of charcoal. *C*, is the upper receiving basin, hollowed out in the lining, as is also the channel, *d*, which leads to the basin. *E*, is the lower receiving basin. *G*, are channels to breathe out the moisture. *K*, is a channel, by which the vapours of the lead in the lower part of the fire-room, *c*, *f*, can escape into the subliming rooms, *z*, at the top of the furnace. *M*, is a blast hole, by which the wind from two bellows is let into the furnace. *P*, a door, level with the throat, or mouth of the furnace, by which it is charged; the side doors open into the subliming rooms, and are only opened occasionally. *T*, in fig. 161, is the upper floor of the laboratory, on which the charge for the furnace is laid out in distinct heaps. *Z*, are subliming rooms connected below with the throat of the furnace, and the side channel, *k*; and opening into the chimney, which rises upwards of sixty feet from the ground.

Trials have been made in building these furnaces with three, and even seven twyer or blast holes; but this increase of blast has not been found advantageous. A real improvement has been made in placing the charging door, *p*, at the back of the furnace, as the workmen are less exposed to the lead smoke issuing from it when opened; and another in making an opening, *q*, in the front of the furnace, sloping upwards, by which the superintendant is enabled to see whether any flame appears during the operation, which ought not to happen.

The washed ore is first smelted with granulated cast-iron in this furnace, by which there are obtained lead for cupelling, and a matt principally composed of sulphur and iron. The matt is taken off as it cools in rounds, and those of the lower basin, which contain also lead united with silver and copper, are slowly roasted in heaps, of about 2000 cwt. each.

The roasted matt is again smelted along with fresh stamped ore, not containing 30 parts of lead in 100, granulated cast-iron, and any slag which it is supposed will yield some profit. This roasting and smelting of the matt obtained in this operation, is repeated four times in all.

The matt thus obtained is again smelted along with the slags of the first operation, in a low blast furnace, by which it is reduced to black copper cakes. The cakes of this black copper are then smelted in a low blast furnace, along

with twice their weight of lead, or an equivalent of litharge, and run into large round cakes, which are heated in a reverberatory furnace, to sweat out the lead, which carries with it the silver contained in the black copper. The sweated cakes of copper are then exposed to greater heat in another furnace, and thus more lead, holding silver, is sweated out, and the copper is prepared for refining.

The lead obtained from all the preceding operations is then cupelled for silver, and the litharge is reduced to saleable lead.

The lead ores extracted near Goslar, in the Hartz, contains calamine mixed with it, and as this is not separated in the washing of the stamped ore, it goes with it into the furnace, and the spelter or zinc is volatilized: hence a peculiar construction of the low blast furnace used in smelting the ore is adopted.

Fig. 162, represents a section of the furnace used at Ocker Hutte, on the line, * *, in the plan; fig. 163, the plan, on a level with the blast hole; and fig. 164, the front view of the furnace. These furnaces are usually built in pairs, that the produce from each being compared together, this comparison may serve as a check upon the workmen.

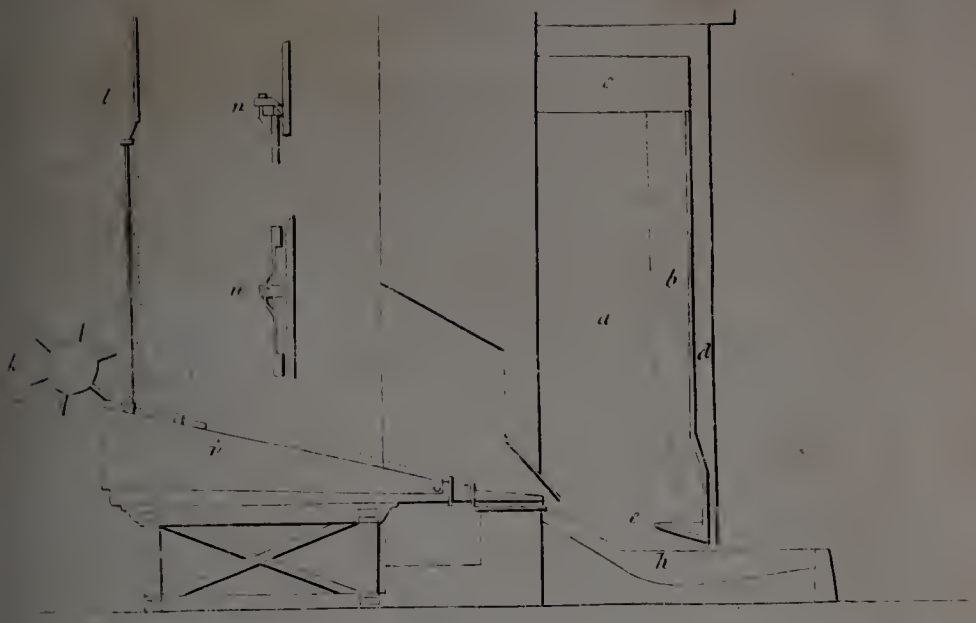
*A*, is the hinder part of the fire-room, which is charged with the ore and large pieces of charcoal. *B*, is the front part of the fire-room, charged with small pieces of charcoal. *C*, is the mouth of the furnace, by which it is charged, there being a scaffold in front with steps, by which the workmen may ascend; the fire-room being about ten feet in height. *D*, the front wall of the fire-room, which is made of thin slates joined by clay to be the cooler, and thus allow the spelter and oxide of zinc to settle upon it. *E*, is a slab of slate placed at the foot of the front wall, to catch the spelter as it drops from the front wall, and conduct it by the groove, *f*, into the side basin, *g*. *H*, is the bottom bed of the furnace, which is made of one part of clay, and two of ground charcoal.

The blast of this furnace is given by two wooden bellows, *i*, which are pressed down by wipers, *k*, on the arbor of a water wheel, and the upper part raised by the action of a rod, *l*, connected with a counterpoise of stones. The left hand bellows *i*, 2, in fig. 163, is represented open, to show the valves, *m*. *N*, shows the manner in which the leathers, fastened to the side of the upper or moveable box, are pressed against the sides of the lower or immoveable box, to prevent the wind of the bellows escaping that way.

The ore smelted in this furnace is sorted in the mine itself into two sorts: lead ore, and copper ore. 100 parts of the lead ore contain only about three of lead, and never more than nine; and the cwt. of this lead does not yield more than a quarter of an ounce of silver: the copper ore is equally poor.

30 cwt. of the lead ore previously roasted three times over, is smelted in 20 or 22 hours, with 10 or 12 cwt. of the slags of the lead mines of Altenau, collected out of the bed of the river Ocker, 3 cwt. of the old slags of the Lower Hartz mines, and 2 cwt. of impure litharge, and refuse of the refining furnaces. During this operation, which produces about 4 cwt. of lead, and a quantity of slags, part of the zinc contained in the ore is reduced to the metallic state, and attaches itself to the front slates of the furnace, from whence it drops down to the groove that conveys it out of the furnace into the side-re-

Fig 162



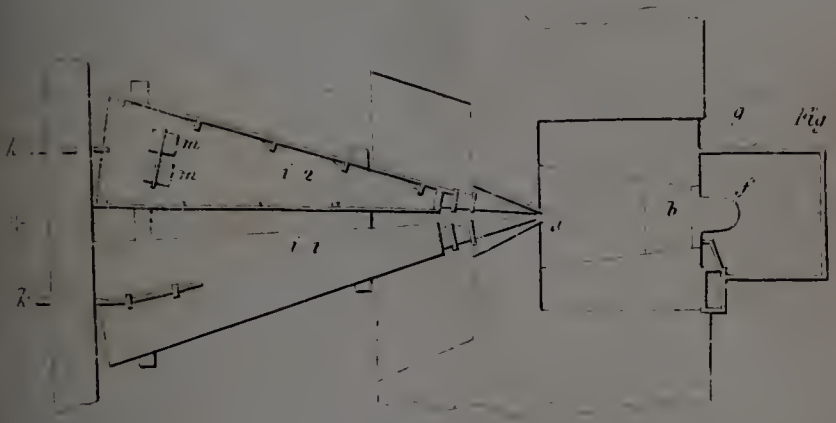
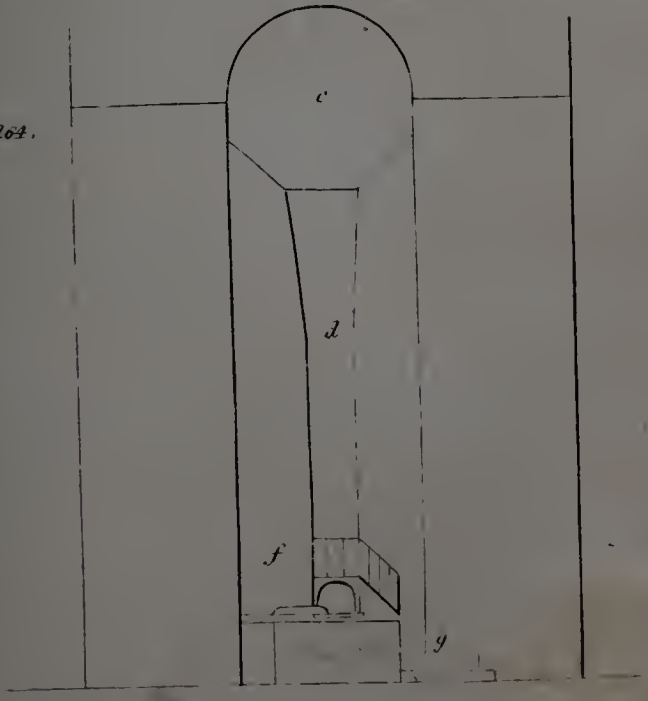
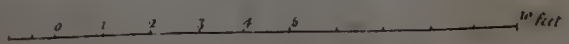




Fig. 164.



ceiving basin. The greatest part of the zinc, however, is burned as fast as it is reduced, and about 2 cwt. of the oxide fixes on the walls of the furnace in each round of thirteen smeltings, that take place every twelve days. These flowers of zinc are used for making brass. The quantity of metallic zinc obtained is very small, and very variable; it never exceeds eight pounds in each smelting.

The lead ores of some countries, as at Wedrin, near Namur, Bleyberg in Carinthia, and Bleyberg near Aix la Chapelle, not being mixed with copper ores, are smelted in a far simpler manner, being only washed and then put into a low blast furnace.

At Wedrin, the ore is mixed with brown oxide of iron, and iron pyrites; the latter only is roasted. 310 cwt. of ore, to which, if poor in iron, the scoria of iron is added, yield, in 160 hours, 100 cwt. of lead; and 106 cwt. of charcoal are consumed. At Bleyberg near Aix la Chapelle, 30 cwt. of washed ore, made into bricks with $2\frac{1}{2}$ cwt. of slaked lime, are smelted with 12 cwt. of the slag of iron fineries; the fusion takes up 24 hours, consumes 8 cwt. of coke, and one of charcoal, and yields about $7\frac{1}{2}$ cwt. of lead.

The lead ore of Northumberland is roasted in a reverberatory furnace, and during this operation a white sublimate collects in the chimney, composed of carbonate of lead and oxide of antimony, which is collected and sold for painting by the name of *lead smoke*. The roasted ore is smelted on a low blast furnace, like fig. 154, along with quicklime: the fuel used is raw coal.

The Chinese reduce lead very expeditiously into very thin sheets. A man sits on a floor with a large stone slab before him, and a moveable flat stone on its edge. His fellow workman, who stands by his side, pours a small quantity of melted lead on the slab, and the first workman instantly dashes down the moveable stone on the melted lead, which presses it out into a flat and thin plate, which he immediately removes from the slab. The rough edges of these plates are then cut off, and they are soldered together for use.

### *Plumbers' Solder,*

Is made by melting together twenty pounds of lead, with ten of tin; in a gentle heat, and pouring it out into moulds made in sand. It is used to join sheets, or pipes of lead together.

### *Printers' Type Metal.*

The basis of type metal is lead, to which the letter-founders add one-fourth its weight of regulus of antimony, and sometimes tin, copper, and zinc, in various proportions; but a good alloy for this purpose is yet wanting. It might probably be improved by uniting the metallic ingredients in the ratio of their atomic weights.

### *Lead Shot.*

Slag, or poisoned lead, is first prepared by melting 20 cwt. of soft pig lead in an iron pot, then strewing a peck of coal ashes or dirt round the edges, to defend the iron from the arsenic, 40lb. of which, either white or yellow, are

then put in, the pot covered, the cover luted with clay, the pot kept red h[illegible] for three hours, then uncovered, the poisoned lead skimmed and ladled o[illegible] into sand moulds.

20 cwt. of soft pig lead are then melted, and the poisoned lead added; trials are made by dropping some of the lead into water from the height of two feet, if the shot be not round, more poisoned lead is to be added. When the proper quantity is added, the metal is ladled out into a cullender, and let to drop into water; the cullender being from 10 to 150 feet or more, above the surface of the water, according to the intended size of the shot.

## *Litharge.*

This is always a secondary product, in the processes for obtaining silver.

Litharge, is the *oxidum plumbicum* of Berzelius, or P b·, equal to 2,789,000; and the *protoxide of lead* of Dr. Thomson, or P b·, equal to 14,000.

Litharge is united with oil, either in a small proportion to make it dry sooner, or in a large proportion, to form a cement for cisterns, or plasters for surgical purposes. It is also used in the composition of glass, as a flux.

## *Red Lead.*

In Germany, 180 pounds of lead are calcined for eight hours upon the hearth of a cupola furnace, and being constantly stirred, it is then left in the furnace for sixteen hours, and only stirred at intervals.

This calcined lead, or massicot, is ground small in a mill with water, washed on tables, and being dried is put into stone pots, of such a size, that 32 pounds fill them somewhat more than a quarter full. Several of these pots are laid horizontally in the colour furnace, so that the flame may go quite round them, and a piece of brick is put before the opening of each pot. A fire is kept up in this furnace for about 48 hours, and the matter in the pots stirred every half hour. The red lead being finished, is then passed through a sieve. In this operation, 100 pounds of lead generally increase 10 pounds in weight.

In England, red lead is made from litharge, which is put into pots, and these being placed in a reverberatory furnace, a gentle fire is kept up for a couple of days, and the litharge frequently stirred.

Red lead is mostly used as a colour. It is the *superoxidum plumbosum* of Berzelius, P b:·, and its weight 2,889,000; and the *deutoxide of lead* of Dr. Thomson, 2 P b $O^3$, and its weight 14,500.

## *White Lead.*

White lead is made by rolling up six pounds and a half of thin cast sheet lead into rolls, so as to leave a small space between each roll. A number of earthenware pots being then half filled with vinegar, the rolls of lead are lightly jammed into the mouth of these pots, so as to be supported above the vinegar. About 560 of these pots are placed in a layer of

pent tanners' bark, confined in a wood frame, and boards being placed over them, and supported by a frame of boards placed endways, a fresh layer of spent tanners' bark is put on the boards, and on this a fresh bed of pots, and so on, until seven beds of pots are made into a stack.

These stacks are then left until the vinegar is completely evaporated, which takes up about three months, when they are pulled down, and the corroded lead is separated from the pot, but as the lead usually sticks so tight in the pot that the labourer is obliged to knock the pot against the box, the dust afflicts the workmen with the Devonshire, or Painters' Colic, and there is much breakage, generally 30 pots in each bed of 560.

In some works each bed consists of only 280 small pots, filled entirely with vinegar, and over these is placed a flooring of boards pierced with gimlet holes, to allow the vapour of the vinegar to pass. Rolls of lead, to the extent of three tons in weight, are placed on this pierced flooring, which is supported by strong boards, placed edgeways round it; and are in like manner covered by another flooring, supported also by boards. By setting the stacks in this manner, the manufacturer obtains $\frac{1}{3}$ more white lead; there is no breakage of the pots, nor, the rolls being well sprinkled with a watering pot with a rose, is there any dust.

A part of the white lead thus obtained is left in the flaky form, by merely unrolling the plates, and is used in fine painting by the name of *flake white*. Another portion is ground with water, made into small lumps, and sold by the name of *ceruse*. But the greater part is ground in water, with certain proportions of chalk, and sold in large lumps by the name of *white lead*.

The sheets of blue lead must be cast rough, for rolled sheet lead is but slightly attacked by the vapour of vinegar.

The principal use of white lead is for paint, not only as a white colour, but also to serve as a body with which other colours, even the darkest, are mixed, on account of its opaqueness.

White lead is the *carbonas plumbicus* of the Northern chemists, $Pb : C^2$ and its weight is 3,339,333; according to Dr. Thomson, and the Southern chemists, who call it *carbonate of lead*, $Pb \cdot C$: its weight is only 16,750. It is the *plumbi subcarbonas* of the present medical faculty.

The German white lead is manufactured from the lead of Bleyberg, in Corinthia, on account of its purity.

The lead is cast by being poured upon a sheet iron plate, and as soon as it begins to fix, the plate is sloped, and thus a sheet of lead is left on it one-forty-eighth, or one-twenty-fourth of an inch in thickness. By cooling the plate with water, several cwt. of blue lead are cast into sheets in a day.

Instead of pots, boxes five feet long, one foot broad, an about ten inches deep, are used. The lower part of the boxe is pitched about an inch high; the upper part has sticks place across. The acid mixture poured into each box is in some ma nufactories made of a gallon each, vinegar and wine lees; i others of 20 pints of wine lees; 8½ pints of vinegar, and pound of pearl-ash. The vinegar is usually made of crab ap ples and water.

The leaves of blue lead being trimmed to a proper size, ar doubled and hung over the sticks in the upper part of the box so as not to touch one another, nor the sides of the box, no the acid liquor. A cover is then put on; and if a dung heat i used, or the mixture contains pearl-ash, the joints are carefull closed with paper pasted over them. The more usual mod is to dispose the boxes in a large room heated by stoves t about 86 deg. Fahr.; a greater heat would evaporate the aci too fast.

In about a fortnight the corrosion is finished, and the sheet of white lead are found near ¼ inch thick, and covered in son places with crystals of sugar of lead. As much as can be g off by a moderate degree of force, is very carefully washe This washing is esteemed the most delicate part of the who manufactory; during the progress of it, a white scum appea which is taken off, and a little pearl-ash being added to it, it changed into white lead, of a beautiful whiteness, and is sol for choice purposes: the remainder is mixed with a pure su phate of barytes, brought from the Tyrol, in different propo tions, according to the market for which it is designed.

In France a solution of lead is first prepared by adding a least 174 pounds of finely ground litharge to 65 pounds of py roligneous acid; of such strength that 22 grains and a half o this acid may saturate 25 grains of well crystallized subcarbo nate of soda; 15 to 20 times as much water is usually added The whole is left for a short time, and the clear being poure off, some fresh acid and water is poured on the sediment, t take up any oxide that might have escaped the action of th first parcel.

The clear solution decanted off the residuum is run int large, but shallow, covered cisterns, and carbonic acid gas i passed into these cisterns by a large number of pipes. Thi carbonic acid gas is procured by the burning of charcoal in close stove, and passing the burnt air into the liquor. Whe no more settling appears to be formed, the whole is passe into a deep cistern, and left there for some hours, when the li quid part is poured off in order to be combined again wit more litharge, some fresh acid being also added.

Part of the sediment left in the cistern is well washed, and roduces a dull milk-white lead with several portions of fresh vater. Generally the washing is not continued to such exactess, because buyers prefer white lead that has a slight bluish inge; now the copper contained in the litharge produces the olour, provided the settling is not washed too much. A gray inge is sometimes preferred; which is produced by adding a mall quantity of common ivory black, which must, however, e well mixed with the white lead.

The white lead is then moulded by putting the well-drained ass into glazed pots of the proper shape to imitate that of the Dutch white lead leaves. These pots are then stoved, and the hite lead packed in pale blue paper, the reflection of which ives it a more agreeable cast of colour.

[This method of manufacturing white lead by precipitating he acetate or pyrolignate, of lead, by carbonic acid, has been ried on the most extensive scale in this country, with great ss and a total failure in the enterprise. A beautiful pigment is ndeed produced to all appearance, when viewed in the mass; ut, owing to some unexplained circumstances, it lacks the peuliar density and opacity of the article prepared in the old mehod, by the corrosion of the metallic lead with the fumes of inegar. It wants those properties which are implied in the ainters' term, *body*.

The manufacture of white lead is carried on extensively in his country by several manufacturers, who obtain their acetic cid by the fermentation of potatos and subsequent distillaion.]

## *Sugar of Lead, or Saccharum.*

This salt is an object of considerable interest, on account of he great use made of it in some arts, as in painting. In the alico printing business it is in reality one of the most usual reparatives, or according to the French term, *mordant*, or iter in.

In the process formerly used, cast lead was cut in pieces by hisels; these cuttings were put into pans, and a small quantiy of vinegar was poured on them, but not sufficient to cover hem. The part which was not sunk beneath the acid becomes xidized in a short time, and as the cuttings were stirred sevral times a day, in order to change the surfaces exposed to the ir, or to the acid, the oxide was gradually dissolved in the viegar. When the acid was saturated with the acid, the liquors n the several pots were poured into a tinned copper boiler, nd boiled down one-third; the liquor was then filtered, and

boiled down again, until on trial, it appeared fit for crystallizing; it was then decanted and set by to crystallize, the first crop was large and white needle-like crystals; but the mother waters, by farther evaporation, yield coloured crystals.

The colour of these crystals appear to be owing to the oil in the wine vinegar.

The Dutch manufacturers use those distilled vinegars that are exempt from oily particles. Distilled cider vinegar, is found to yield a very pure saccharum, even to the last drop, which is as beautiful as the first; pyroligneous acid, carefully freed from the tar, is now used in England and France.

As 100 parts of saccharum are composed of 58 of oxide of lead, 26 of dry acetic acid, and 16 of water; of course, the saturating power of the pyroligneous acid must be examined. When this acid is at eight degrees of Baumé's hydrometer, it generally requires 68 pounds of it to be poured on 58 pounds of litharge. The solution takes place immediately, and is so quickly made that a considerable heat is produced, which retains the sugar of lead in solution; but a little fire is usually given, and some water added, to keep up this solution until the liquor has become clear, and it is then poured into crystallizing pans.

The crystals usually weigh 75 pounds; they are drained and carefully dried. The mother water, which contains about 25 pounds of the saccharum, yields, by evaporation, great part of its content, but the crystals are by no means so fine as the former. When the mother water no longer yields crystals, it is mixed with subcarbonate of soda; a carbonate of lead falls down, which is used instead of litharge, in future operations.

It will be found preferable at first to add the mother water to the acid and litharge, and thus nearly 100 pounds of good sugar of lead will be obtained instead of 75 pounds, by the first crystallization; but this method cannot be continued for any time, as the liquor will become greasy, the crystallization will be hindered, and the sugar of lead becomes difficult to drain; so that it is then necessary to abstain from adding the mother water any longer to the solution, and to decompose it by subcarbonate of soda.

To obtain a very white sugar of lead the metal or litharge should have no admixture of copper; the copper, however, gives the sugar of lead a slight bluish tinge which pleases the eye of many of the buyers.

In this solution of the litharge in the acid, there remains a very small residuum, which may be treated as an ore of silver, as it is composed of that metal, united with oxide of copper, of lead, and some earthy substances.

It is a great advantage in this manner of forming sugar of lead, that it is not necessary to evaporate the solution, for the solution is decomposed by being boiled, and part of the sugar of lead is changed into white lead, and of course separates in the form of a powder.

[The following is the method of preparing the pyrolignate, or brown sugar of lead in Lancashire.—Saturate the re-distilled pyroligneous acid in a copper boiler with litharge; allow the oxide of lead not dissolved to subside; then decant the clear liquor into another boiler and evaporate the clear solution of sub-acetate of lead till a drop let fall upon a cold stone crystallizes, or sets hard, which may take place at 1·980; now add to the liquor one half its bulk of the strongest distilled pyroligneous acid, and evaporate again till when poured upon a cold stone minute centres of crystallization form in various parts, and successive circles appear, of which each spot is a centre, forming an appearance similar to knots of mahogany. Lastly, pour the liquor into a shallow copper vessel, when it will concrete into a solid mass.]

Sugar of lead water is used to ascertain the presence of sulphuretted hydrogen, or hydro-sulphuretted alkalies in mineral waters, as also of boracic and carbonic acid.

Sugar of lead is the *acetas plumbicus cum aqua* of Berzelius, and the northern chemists, or P: A—$^{2}$+6 H$^{2}$ O, and its weight 4,750,800. Dr. T. Thomson, and the southern schools call it *acetate of lead*, or P· A—+3 H. equal to 23,625.

## *Nitric Solution of Lead.*

Cuttings of lead, or granulated lead, dissolve easily in weak nitric acid of any kind.

[The solution of metallic lead, even when in a state of minute mechanical division, is far from being effected with the facility, which is desirable in the manufacture of the article on a large scale. The more usual method is to dissolve litharge in single aqua fortis to saturation heated in an earthen vessel in a hot water bath; the saturated hot solution deposites crystals on cooling. A more ingenious method has been devised by Dr. Warwick. He dissolves 30 lbs. of sugar of lead in 10 gallons of water, and then saturates the solution at a boiling heat with litharge, of which it will require a considerable quantity, and form a sub-acetate. To this, when cold, he adds as much triple aqua fortis as will decompose the whole acetate of lead; it may require about 34 lbs. Pour the liquor from the nitrate of lead, which will fall down in minute crystals into an earthen vessel. Saturate again with litharge, and proceed as before. The object of this process is to take advantage of the superior solvent power of the acetic over that of the nitric acid over the oxide of lead. The same acetic acid will serve for any number of times, and both acids are sufficiently concentrated to supersede the necessity of evaporation altogether. For immediate use, the crystals of nitrate of lead may be used in this state; but for sale they should be dissolved in boiling water and recrystallized slowly.

This salt is now much used in calico printing.]

Wooden sticks, impregnated with nitric solution of lead, are recommended by Proust to be used to fire artillery, instead of the port fires usually employed.

### *Turner's Patent Yellow.*

This metallic colour may be made by pouring upon litharge one-third of its weight of strong muriatic acid, and after letting it stand, for 24 hours, melting the whitened litharge, by which it becomes yellow.

It is also prepared by rubbing red lead or litharge along with one-fourth its weight of common salt, and a little water, exposing the mass to heat, and then washing out the carbonate of soda from the mineral yellow.

It is used as a paint, but the superior beauty of chromate of lead has diminished its consumption: its use was, however, a great relief to the coach-painters, most of whom formerly fell early victims to the fumes of the orpiment formerly used; as a bright yellow was, and will, probably, ever continue the favourite colour for carriages.

## TIN.

THERE are several sorts of this metal in the market.

*Cornish block tin*, in large blocks of about 300 pounds each, or small blocks of 30 or 35 pounds; this is obtained from tin ore mixed with copper pyrites; it does not contain more than one-five hundredth of other metals; seldom, indeed, more than one-thousandth of copper, which, when the metal is dissolved, separates in the form of a black oxide; represented by the advocates of medical police as arsenic.

*Refined block tin*, in small ingots of from one pound and a half to two pounds, or in rods of a half pound each.

*Grain tin*, in blocks of 120 or 130 pounds, but is generally in fragments resembling rocks, which form is given it by letting the blocks fall from a great height while hot. It is obtained from the pure oxide of tin, of the stream works of Cornwall, very brilliant, and the purest English tin: seldom containing more than one-ten thousandth of iron, and is usually 20*s*. or 30*s*. by the cwt. dearer than block tin.

*German tin*, in bricks of about 8 or 10 pounds each; it contains much iron, and is liable to become spotty with rust.

*Malacca tin*, imported from the East Indies in pyramidal ingots, of different sizes, from a half pound to one pound and a quarter. This is esteemed the purest kind, and used in making organ pipes, and other nice work.

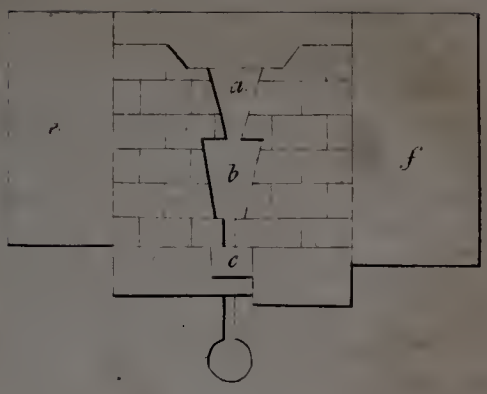
*Banca tin*, from Siam, in flat blocks of 120 or 130 pounds: also very pure.

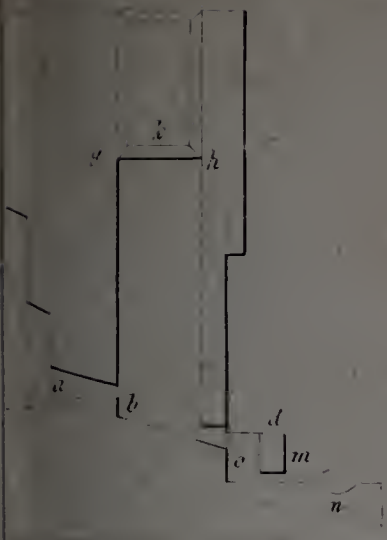
### *German Tin.*

This tin is usually found in the form of oxide, and smelted in blast furnaces, which, in different countries, vary in height: the ore being first stamped and washed.

Fig. 165, is the plan, on a level with the blast hole, of the low blast furnaces used with some slight variations in Cornwall and Saxony for smelting tin. Fig. 166, is the vertical section.

Fig. 165.




For Fig. 165. & 166.

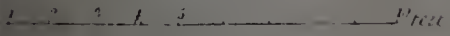



Fig. 167.

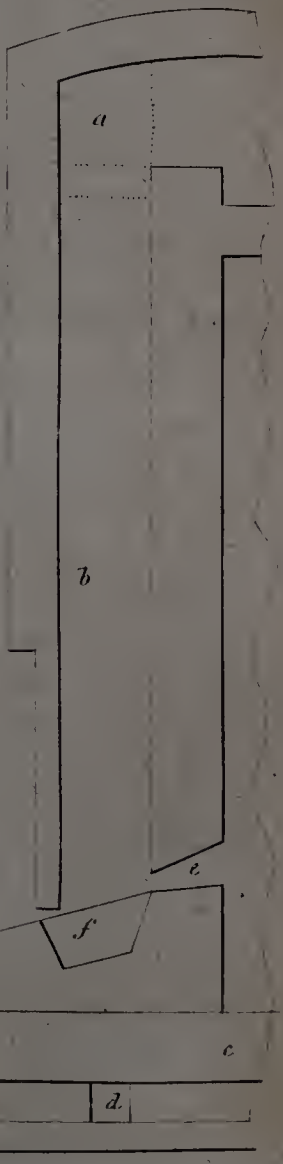



Fig. 168.

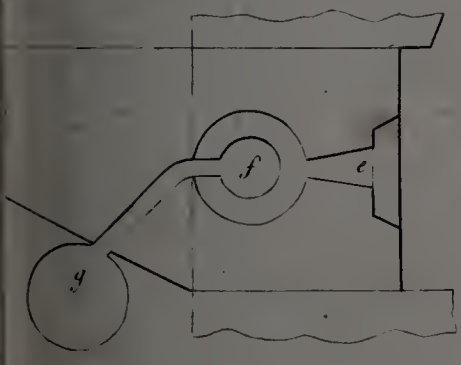
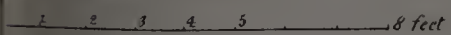



Fig. 167. & 168.



*A*, is the twyer, or blast hole, which admits the blast of a pair of wooden bellows, or that of a blowing cylinder. *B*, the bed of the furnace, made either of clay or a granite slab. *C*, the upper basin, to receive the matters that flow out of the eye of the furnace. *D*, a ridge of stone on which a little small charcoal is kept to sprinkle occasionally on the tin collected in the basin, *c*. *E*, *f*, are two strong side walls, in one of which is the charging door, *k*; opposite to this is another door, opening into a subliming room, as shown in fig. 166, by the dotted lines. The use of this subliming chamber is not adopted in the English furnace. *G*, *h*, and *b*, is the fire-room. *K*, is the opening by which the ore and coal are flung into the fire-room. *L*, *m*, is the floor of the laboratory, on which the tin runs from the upper basin, *c*, into a lower basin, *n*, as often as the eye of the furnace, *m*, is pierced.

This furnace is generally from six to eight feet high, from the bed to the opening by which it is charged.

At Slackenwald, in Bohemia, the tin ore which is mixed with iron pyrites and arsenical pyrites, is first stamped, washed, and roasted, in parcels of 4 cwt. in a reverberatory furnace, for from 3 to 6 hours. The white arsenic is collected in a subliming room, about 300 feet long, forming a horizontal communication between the furnace and its chimney. This subliming room is opened twice a year, and about 50 cwt. of white arsenic extracted each time. Part of the white arsenic is distilled with sulphur in cast-iron retorts, and thus made into red and yellow arsenic.

The roasted ore is washed upon sleeping tables, and the pyrites now rendered lighter, carried off by the water; which also takes away about fourteen pounds of copperas from each 40 cwt. of roasted ore.

10 cwt. of this washed ore, well moistened, is then smelted every 24 hours in a low furnace, with moistened charcoal, to damp the fire. The smelting lasts about 16 hours, and the eye being pierced four times, about 4 cwt. of tin are obtained; 100 cubic feet, or 920 pounds of charcoal, are consumed.

Fig. 167, represents the vertical section of the high furnaces used also at Slackenwald, in Bohemia, for this smelting. Fig. 168, is the plan of the furnace, on the level of the blast hole.

*A*, is the charging door, just over the fire-room, and at the commencement of the subliming room, which is constructed over the furnace, and is only indicated in the figure. *B*, is the fire-room, which is about fifteen feet high. *C*, the foundation of the furnace, below the floor, with its channel, *d*, for breathing out the moisture. *E*, the blast hole. *F*, the upper basin, lined with clay and charcoal dust mixed. *G*, the lower basin, into which the metal runs when the eye is pierced.

A continual smelting is kept up in these furnaces for a fortnight, during which time 300 cwt. of dressed ore, yields 125 cwt. of tin, and about 210 cwt. of charcoal is consumed. Hence, this furnace consumes only seven-tenths of the charcoal that would be required for the smelting of the same quantity of ore in the low blast furnaces; and there is a still greater saving of

time, as this high furnace furnishes twice the quantity of metal in a day more than the other.

These high blast furnaces, however, although a trial has been made of them in Cornwall, have not been approved there, probably from want of knowing the minute attention which certain parts of the process may require.

### *Grain Tin.*

In Cornwall, the alluvial tin ore, or stream tin, obtained from the stream works, and which is composed of pure oxide of tin, without any admixture of pyrites, arsenic, blende, or copper, is smelted in blowing houses, in low blast furnaces like the German, but open at top; 15 cwt. of clean ore generally yields in twelve hours 10 cwt. of grain tin, and the smelting consumes 280 cubic feet, or about 23 cwt. of charcoal. The bottom of the furnace is a mere slab of granite, and the eye being always open, the metal runs in a channel three feet long, in order to allow the slag to be taken off into a basin; from whence it is ladled into an iron kettle, where it is refined by keeping pieces of charcoal soaked in water, under its surface, then scummed, and laded into moulds.

The slags are passed four times through the same furnace; and afterwards stamped, to separate any metallic grains.

### *Mine Block Tin.*

The mine tin of Cornwall, or that extracted from the veins in the mines, is stamped, washed, and then roasted in a reverberatory furnace. The roasted ore is then stamped and washed again, until it becomes so clean as to yield by assay, one-half or three-fourths its weight of tin. It is then sold to the smelting houses.

The roasted ore is mixed with a little coal, or Welch culm, and some slaked lime, the whole well moistened, and smelted in a reverberatory furnace, which is seven feet long, five broad, and about fifteen inches deep, 7 cwt. of the ore are smelted at once, and yield about two-thirds its weight of tin.

To obtain 100 pounds of tin, there is consumed, in the roastings, 38 pounds of coal, and in the smelting, 170 pounds; in all, 208 pounds of coal.

The tin that remains in the slag, is separated by stamping and washing, and is called *prillion;* it is then melted into a mass.

### *Refined Block Tin.*

This block, or common tin, is refined by melting it by a gentle heat, on the bed of a reverberatory furnace, and allowing

t to run as it melts, into an iron kettle, with a small fire under t: the least fusible substances that may be present, are left on he bed. The tin in the kettle is farther refined, by taking it up n a ladle, and pouring it repeatedly into the kettle again, kimming it, and finally keeping it melted for some time, and ading out only the upper part.

### *Silvering and Gilding by Powdered Tin.*

A quantity of pure tin is melted and poured into a box, which s then violently shaken; the metal assumes when cold the form f a very fine gray powder. This is then sifted to separate any oarse particles, and is mixed with melted glue.

When it is to be applied it should be reduced by the addition f water to the consistence of thin cream, and is laid on with soft brush, like ordinary paint. It appears when dry like a oat of common gray water colour, until it is gone over with n agate burnisher, then it exhibits a bright uniform surface of olished tin. If the glue is too strong, the burnisher has no ffect; and if too weak, the tin crumbles off under the agate. A oating of white or gold coloured oil varnish or lacquer, is imediately laid over it, according as it may be intended to imiate silvering or gilding.

It is used for covering wood, leather, iron, or other articles in constant wear, s it is very ornamental, and resists the effects of the weather.

### *Pewter.*

There are three kinds of pewter.

1. *Plate Pewter*, used for dishes and plates; this is the best kind, and contains the smallest quantity of other metals added o the tin, which forms the basis of all sorts of pewter. Seventeen pounds of regulus of antimony, added to 100 of tin, form good plate pewter; some add a small quantity of copper, inc, or bismuth. A very fine silver-looking metal is made rom 100 pounds of tin, melted with 8 of regulus, 4 of copper, nd 1 of bismuth.

2. *Trifle pewter* is used for making the pots for drinking eer; its quality is inferior to the plate pewter.

3. *Ley pewter* is used for wine measures, and large vessels; rom its specific gravity it must contain more than one-fifth of ead.

The use of pewter vessels has been represented by the advocates of medical olice, and persons interested in the pottery business, as unwholesome. The llowing experiments show the error of this opinion. Nine vessels of different qualities of pewter were cast, and filled with boiling vinegar, and kept for hree days. The vinegar of the eight first vessels when assayed by means of

the sulphate of potash, did not present the slightest portion of dissolved lead; the ninth was charged with the latter metal. Hydro-sulphuretted water discovered the tin which was dissolved in the eight first liquids.

These experiments were repeated three times with vinegar of different strength, and the same results were obtained. The tin, which is always more soluble and more easy to be oxidated than the lead, easily suffers itself to be attacked by the vinegar, but the lead not at all. The vessels, after the vinegar has been kept in them, appear, indeed, of a leaden colour, and to abound more with lead than the piece does in its substance; but the slightest friction detaches the light stratum which is formed at the surface, and restores the vessel to its original state.

It is well known that the poorest pewter, such as that of 20 per cent. is never employed in the fabrication of the utensils which serve for preparing and preserving our aliments and drinks. But even though a dishonest pewterer should employ it, his alloy can never be injurious to health, since vinegar may be kept in vessels alloyed with 33 or 50 per cent. of lead, without its being possible to detect a sensible quantity of this metal in it. And as to the arsenic which Malouin, Geoffroy, and Margraaf had detected in some tin, the supposed danger thence arising, was soon dissipated by the work which Bayen wrote upon this subject by order of the police of Paris, and in which he observes that a pewter plate which he had employed for two years at all his meals, had lost only four grains of its weight, and that the arsenic which could be contained in these four grains, detached by scouring the plate, rather than introduced into the stomach, did not amount probably to one five thousand seven hundred and eightieth of a grain per day.

### *Biddery Ware.*

Biddery ware is of a black colour, and as it never fades, and when tarnished may be easily made to look as if new, might be used more advantageously for the formation of ink stands, and some similar articles, than the brown bronze now in use for the finer articles of that description.

Biddery ware is made by adding 24 pounds of tin to one pound of copper in a melted state. The mixed metal is of course in this stage of a white colour, and is made into the required form by the usual method used in casting small articles. The article being cast, and, if necessary, dressed, it is then scraped with a knife, and coloured of a lasting black colour. Equal parts of sal ammoniac in powder, and of the reddish saltpetre earth found in the neighbourhood of Biddery, are made into a paste with a little water, and rubbed on the metal, which instantaneously assumes a lasting black colour. Sometimes, indeed, this ware gets a little tarnished, and acquires a brownish colour, but the fine sable hue is immediately restored, on the article being merely rubbed with a little oil or butter.

In some other places of India they melt together 16 ounces of copper, 4 of lead, and 2 of tin, and having poured out this metal into ingots, they then melt 3 ounces of this mixed metal along with 16 of spelter, and cast their articles in the usual way.

As the saltpetre earth contains not only saltpetre but also common salt, so in places where it cannot be procured, the articles are washed with a solution of 1 ounce of sal ammoniac, a quarter ounce of saltpetre, another quarter ounce of common salt, and the fifth part of an ounce of blue vitriol, which last might probably be omitted.

### [*Muriate of Tin.*

Take the best grain tin; reduce it to a state of minute division by pouring it while melted, and near a red heat by day light, from a height into a large vessel of cold water; fill with this feathered tin, as it is called, the third, fourth, fifth, and sixth receivers when distilling muriatic acid, as already described, and then add to each receiver six gallons of water. The salt is formed in the process of distillation. When the solution is cold, pour it into a copper boiler, which should be filled, at least, one-fourth full of feathered tin to prevent the action of the muriatic acid on the copper. The tin must be replenished as it dissolves away. Evaporate the solution to 1.960; let it stand an hour or two, and pour the clear liquor into shallow earthen vessels of about two gallons each. The crystals of muriate of tin will form in the course of a few hours. Pour the mother water back into the boiler, and drain the crystals. Evaporate and repeat the process.

### *Oxymuriate of Tin.*

This is the permuriate of tin of the more modern nomenclature, which, with the foregoing, are salts of great importance in the arts of dyeing and calico printing. The usual method of preparing the oxymuriate of tin, is this:—Take four parts of double aqua fortis, at 1.320 or 64′ of Tweedale's hydrometer, and one part of the very best and strongest muriatic acid; it should have a specific gravity of 34° T. Mix the acids, and add grain tin in lumps of half pound each successively as they dissolve, until the liquor acquires a specific gravity of 1.600 or 120° T.

Dr. Warwick's method is, to take the strongest solution of muriate of tin, (say at 140° T., as obtained from the receivers in the process of making the muriate of tin,) and mix it with double aqua fortis, in the proportion of one measure of the former to two of the latter; then add tin by degrees till the solution acquires a specific gravity of 120° T. or 1.600, water being one.

Another and more recent method practised by the same intelligent chemist, and to which he gives the preference, is this:—Take one pound of the finest and most silky crystals of tin,

and pour upon them eight ounces of double aqua fortis, and mix well together. If the action does not commence immediately, apply the heat of a candle or burning paper to the outside of the vessel, when a violent effervescence will take place: as soon as the fumes will allow the operator to approach the vessel, stir the mixture till the action is over. The violence of the action of the materials in this process approaches almost to an explosion, and the operation requires considerable caution in the management of it.

In the first of the three foregoing processes the tin is wholly oxidized at the expense of the nitric acid. In both of the last the protoxide of tin is formed at the expense of the water, as the muriatic acid affords no oxygen. The second process is rather the cheapest. The last is the most expensive on account of the muriate of tin being required in the crystalline form. The product of the last process contains less excess of acid, which is unnecessary for the purpose of the calico printer, and objectionable on account of the alkali, which is taken up in neutralizing it. A large excess of acid is, however, generally considered as advantageous in the woollen dyes, and a preference may, therefore, be given for those purposes to the first or second preparation.

Dyers are frequently much troubled with this preparation on account of its assuming a concrete and gelatinous consistence and an opal colour. This effect is sometimes produced by the addition of water; in relation to this subject, Dr. Ure observes that "the uncertainty attending these experiments with the solution of tin in aqua regia seems to depend upon the want of a sufficient degree of accuracy in ascertaining the specific gravities of the two acids, which are mixed, the quantities of each, and of the tin, together with that of the water added. It is probable that the spontaneous assumption of the concrete state depends upon the absorption of water from the atmosphere." This preparation is likewise liable to become milky from the precipitation of a part of the oxide of tin, or, perhaps more properly, a submuriate of that metal. On this account an excess of acid is favourable to its preservation.

It is often desirable to distinguish between solutions of the muriate, and the oxymuriate or nitromuriate of tin, as both are now generally manufactured for the dyer's use in the liquid form, and are not unfrequently mistaken the one for the other, to the loss and perplexity of the dyer, for no two preparations are more unlike in their chemical relations. The muriate of tin forms a black precipitate with a solution of corrosive sublimate, and a purple infusion with a watery decoction of cochineal. The

ermuriate, oxymuriate, or nitromuriate, on the other hand, affords no precipitate with the salts of mercury, but gives a scarlet colour to the decoction of cochineal.

Both the oxymuriate, and the solution of the muriate, of tin should be kept excluded from the air; in the former case to prevent the absorption of moisture, and in the latter the absorption of oxygen from the atmosphere.]

### COPPER.

Copper is sold in various forms, as in cakes, bean shot, feathered shot, and Japan copper; the latter has its external surface of a fine red colour.

The good quality of copper is shown by its capability of alloying silver, without any diminution of its extensibility under the hammer or rollers. The Swedish copper is the best copper in this respect; but lately the Danes, or rather Norwegians, have forged the Swedish mark, affixed it to an inferior metal, and thus caused a depreciation of that article.

The platers in Birmingham and its neighbourhood, seek after the copper coins of Anne, and the first and second George, and give twice their nominal value for them; these coins, from the dark patina which they have acquired, and their softness, as shown by the considerable obliterations of their impression, appear to have been made of real Swedish copper. Our English copper will not stand this proof, and is of very inferior quality.

### *Foreign Copper.*

The foreign copper ores are usually roasted in piles, smelted through the coals in blast furnaces of different heights, and when the ore is reduced to the state of black copper, it is alloyed with a large proportion of lead, the greater part of the lead sweated out to carry off any small quantity of silver and gold that the copper may contain, and the sweated cakes of copper are submitted to a slight cupellation in a reverberatory furnace, to get rid of the remainder of the lead. So that the treatment is, as usual, much more complex than in England, and the entire process lasts several months; but, in return, for this labour, almost every particle of metal, except iron, is extracted from the ore and brought to sale. Every separate parcel of ore is also carefully assayed as soon as it is brought in, generally by three assayers, the mine proprietors', the smelting-house proprietors', and the workmen's, and the ore mixed in such proportion as that the next round of smelting may form a uniform mixture; by which means, as each separate smelting ought to produce a similar yield of metal, a considerable check is held on the workmen. The slags are also assayed, and mixed in the same manner, for the same purpose.

High blast furnaces are employed to smelt the slaty copper ore of Hesse. These furnaces have two receiving basins, which are used alternately. The

bottom of the fire-room is lined with a mixture of clay and charcoal dust, and is about eighteen feet high.

Nine hundred and twenty-four cubic feet, or about 4080 cwt. of the slate is first roasted in a heap, on a layer of brush wood, and then smelted by degrees, by hourly charges, so that 153 cwt. of the roasted slate, and 522 cubic feet, or 62 cwt. of beech and oak charcoal, pass through the furnace every 24 hours. Every 12 hours one eye of the furnace is stopped up and the other opened. The usual produce in 24 hours is from seven to nine cwt. of copper matt, and some slag mixed with matt, which is flung again into the furnace.

The copper matt is roasted in kilns, holding 250 cwt. ten times successively; by means of 420 fagots of brush wood, 525 cubic feet of beech wood, and 210 cubic feet of beech charcoal. The roasted matt is then smelted again in a lower blast furnace, only seven feet high. Forty-six cwt. of roasted matt with nine cwt. of the slags of the first smelting, and 25 cwt. of beech charcoal produce 16 cwt. of black copper, and 5 cwt. ¾ of a matt which is smelted again; the black copper is refined on a forge hearth, as hereafter described.

One hundred cwt. of saleable copper requires, for its production, 5712 cwt. of this slate, and the consumption of 28,67 cubic feet, or 3451 cwt. of beech and oak charcoal, besides a very considerable quantity of wood for roasting the matt, as stated above.

Fig. 169 represents the vertical section of the furnaces, lately brought into use at Fahlun, in Sweden, for smelting copper ore; and fig. 170 is the plan of the same, on the level of the three blast holes, or twyers, *a*, which form the principal peculiarity in the construction of this furnace. Two common wooden bellows are placed behind the furnace, which, by means of a wooden box, send the blast to the three blast pipes.

This furnace is charged by an opening, *b c*, in the side, to which the workmen get up by means of steps; *D* are plates of sheet iron built in the chimney, for the purpose of stopping the sparks emitted by the fire, which might, otherwise, endanger the burning of the surrounding buildings; a precaution of this kind is usually adopted in the Swedish mine works, on account of their being carried on in wooden buildings. *E* is the receiving basin.

These furnaces are esteemed a great improvement of the common blast furnaces, as consuming less charcoal, and producing more copper than the ordinary kind; hence it is intended, as the present furnaces wear out, to rebuild them on this plan.

In the Hartz, as soon as all the silver is sweated out of the smelted copper by means of lead, the copper is refined on a small forge hearth.

Fig. 171 represents the front view of this forge hearth, or copper refinery. Fig. 172 is the plan at the level of the blast hole, and fig. 173 is the vertical section in the line *, *, in the plan.

Fig. 170.

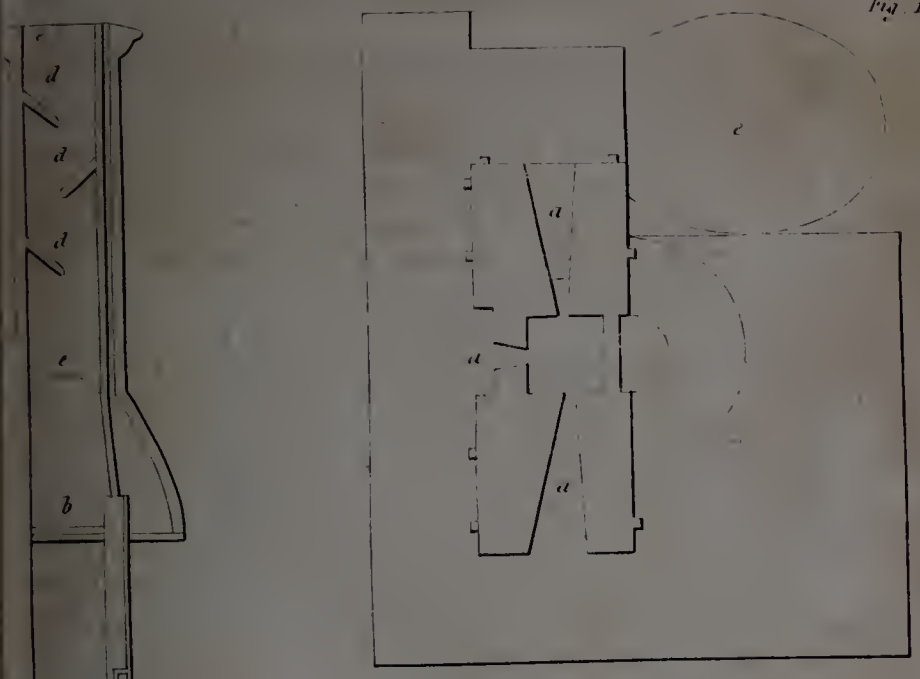



Fig. 172.

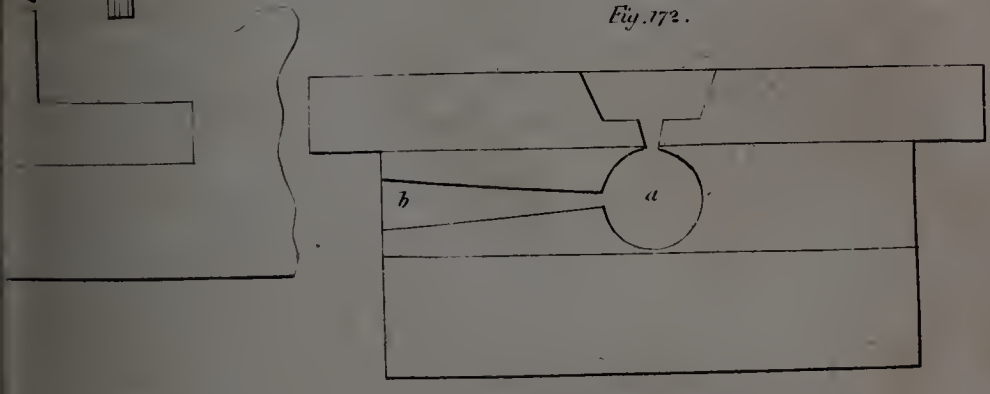


Fig. 171.

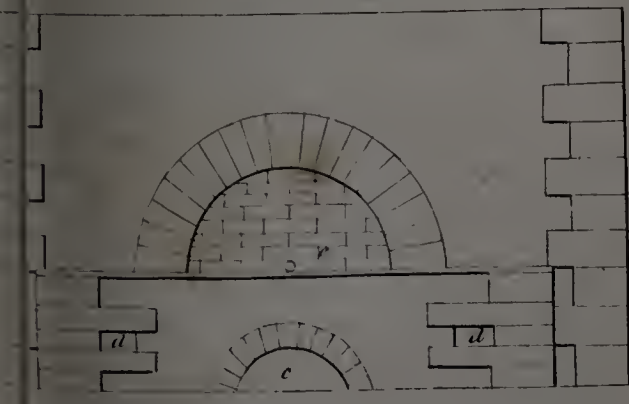
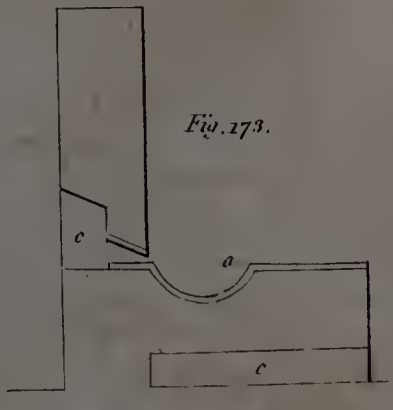



Fig. 173.



*A*, is the refining basin, lined with a mixture of 2 parts of clay with 1 of charcoal dust; on one side of this basin is a sloping channel, *b*, by which the slags are run off. *C*, is an arch under the refining basin, which, with two other channels, *d*, are to breathe out the moisture. The twyer is at *e*.

The refining of copper on this hearth is performed by smelting it amongst the charcoal; and the blast pipe being inclined downwards, drives the air upon the surface, keeps it in continual motion, and, by favouring the oxidation and vitrefaction of the impurities, the slag is speedily formed, and are run off by the side passage left for it.

At Altenau and Andreasberg a cwt. and a half of black copper from the sweating furnace is refined in 2 or 3 hours $\frac{1}{2}$, according to its impurity, and generally produces 1 cwt. $\frac{1}{4}$ of saleable copper; 1 cwt. $\frac{3}{4}$ of charcoal of resinous wood is consumed.

The purer the black copper, the more may be refined at once, but at the Hartz furnaces not more than 3 cwt. are ever attempted. In the Russian mine works, 8 cwt. of copper are sometimes refined at one time; the refining lasts six hours, and consumes 3 cwt. $\frac{1}{4}$ of charcoal made of resinous wood. They even use still larger hearths, capable of refining 33 cwt. of copper at once, which they let run out by successive piercings of the furnace.

A reverberatory or cupola furnace, similar to that used for cupellation, is also in general use in the Hartz, the Prussian and Saxon Mansfield, Hungary and other countries, for refining arsenical copper matt into black copper, and black copper into saleable copper.

In these furnaces the fuel is burned upon a grate, over a high ash room and the fire room is covered with an arch contiguous to the cupola of the furnace. There is a door by which the bed of the furnace is charged with the matters to be smelted, and another door by which the slags that swim on the melted metal are taken out of the furnace. These furnaces have two eyes in the bed of the cupola, which are occasionally pierced, to let the melted metal run into one or other of the receiving basins, which are used alternately; these basins are lined with a mixture of clay and charcoal dust. There are also two blast holes by which the blast of two bellows are admitted into the cupola. The bed of the cupola is composed of, 1, a layer of slags; 2, a layer of clay; 3, a layer of a mixture of clay and charcoal dust.

At Rammelsberg in the Hartz, the arsenicated copper matt obtained by smelting some of the slags, is remelted in a furnace of this kind, and exposed to the blast of the bellows in order to drive off the arsenic and advance the purification of

the copper. The bed is lined with a mixture of 2 parts of clay and 3 of charcoal. Thirty cwt. of the arsenicated copper matt are then placed on it, and a clear fire of wood is applied for 14 or 15 hours; the metal is then let out of the bed into one of the basins, and 10 or 12 cwt. of black copper are usually obtained. The bed is then prepared afresh, which takes four hours' work, and a new operation begun.

This black copper is farther refined into saleable copper in a similar furnace. 27 cwt. are worked in each operation, which lasts 12 or 14 hours, and yields 20 to 23 cwt. of saleable copper. The bed must be very carefully prepared and dried, so that it takes 6 hours to make it.

The same kind of furnace is used at Andreasberg for smelting the matts; which are highly loaded with arsenic, and by this means to obtain a purer matt, and lead fit for cupellation.

The French have attempted to improve the construction of these cupola fining furnaces.

Fig. 174, is the plan of the furnace used in the Lyonnais, in France, for fining copper. Figs. 175 and 176, are vertical sections, in different directions, of this furnace; the first in the line *z*, *z*; the second in the line, *y*, *y*.

This copper finery is a reverberatory, bearing a considerable resemblance to the cupolas used in the Hartz, but having a high chimney. *A*, is the ash-room, and air-draught of the furnace. *B*, is the fire-room and grate. *C*, is the bed on which the copper is smelted, the lower part of which, *d*, is formed of layers of slag of different finenesses, and the upper part, *e*, of clay mixed with charcoal dust. *F*, are channels by which the moisture of the bed is breathed out. *G*, are two receiving basins into which the copper is run, when it is sufficiently refined. *H*, are two bellows which direct a blast of air on the surface of the melted copper. *I*, is an opening by which the metal on the bed is stirred, and the slags on its surface drawn out by an iron hoe. *K*, openings into the chamber, kept stopped during the fining, and then opened to give a passage for the copper to run into the receiving basins, *g*. *L*, the chimney.

The copper to be refined is placed on the bed, a layer of straw being first laid down to prevent the bed from being injured by the blocks. The bed of the furnace delineated is calculated to be sufficient to refine 2500 myriagrammes, (550 cwt.) at a time. When the copper is melted, the blast of the bellows is directed on the surface for about two hours, and the slag as it forms is drawn out by the opening for that purpose. The copper being judged to be sufficiently refined, one of the eyes of the furnace is opened, and the copper is allowed to run out into the basin connected with it. As soon as the surface is fixed a little water is thrown upon it, and the crust is taken out; this is repeated until the whole of the copper is cooled and taken off in crusts. Great care must be taken that the surface of the copper is completely fixed all over before the water is thrown on it, as should any of the water touch the fluid metal an explosion would take place.

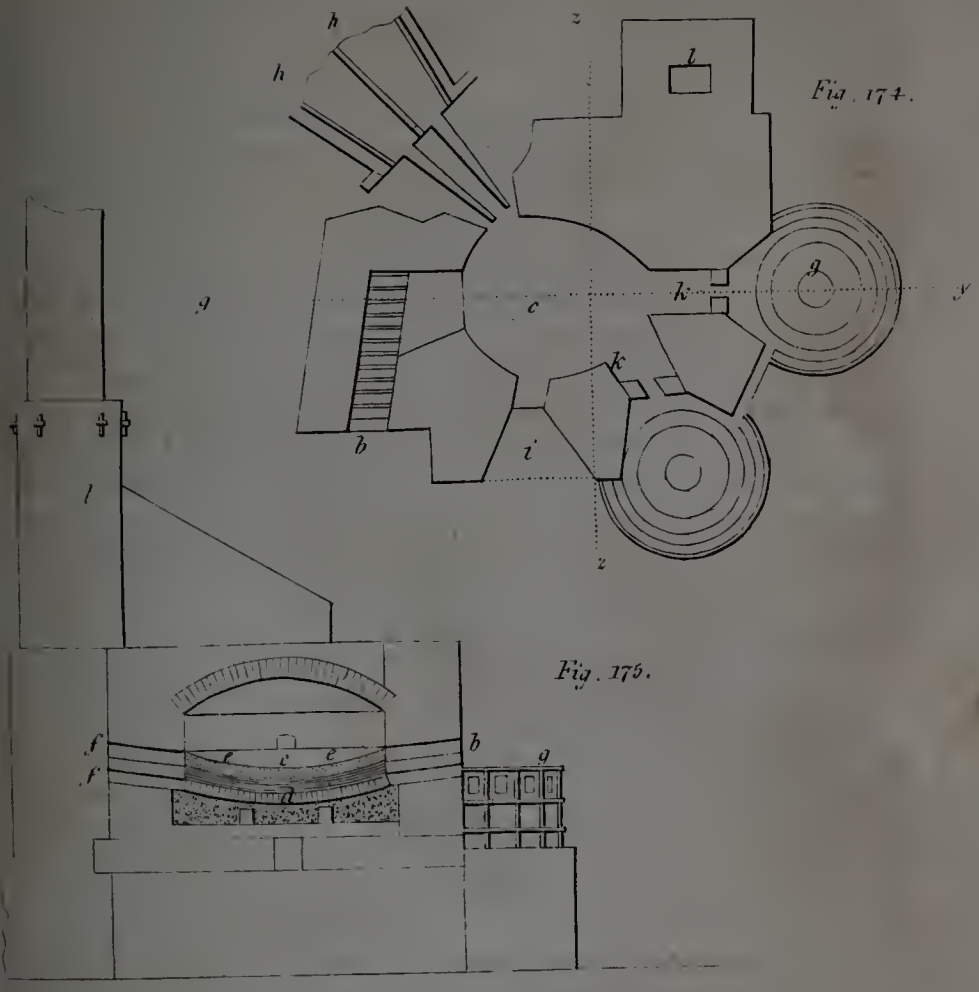



Fig. 174.

Fig. 175.

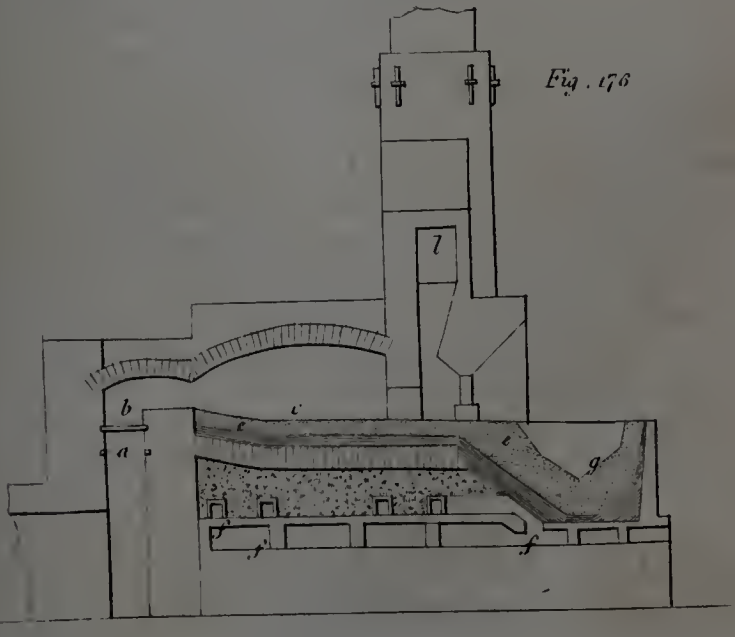



Fig. 176

## *English Copper.*

The copper ores smelted in the works in South Wales are for the most part raised in the mines of Cornwall and Devon. They consist chiefly of yellow copper ore, or copper pyrites, and the gray sulphuret of copper. The average produce in copper may be stated at 8½ parts from 100 of ore.

The ores are conveyed from Cornwall to the neighbourhood of the coal mines, in Wales, to be smelted. The processes are, as usual in England, very slovenly, as the sulphur is burned to waste, and the after treatment of the ore consists only of alternate calcinations and fusions, so that the copper obtained is very harsh and hard. The furnaces in which these operations are performed, are reverberatory, and of the usual construction. The calcining furnaces, or calciners, are furnished with four doors or openings, two on each side the furnace, for the convenience of stirring the ore, and drawing it out of the furnace. They are commonly from 17 to 19 feet in length from the bridge to the flue, and from 14 to 16 in width; the fire-place from 4½ to five feet across, by three feet.

The melting furnaces are much smaller than the calciners, not exceeding 11, or 11½ feet in length, by 7½ or eight feet in the broadest part; the fire-place is larger in proportion to the body of the furnace, than in the calciners, being usually from 3½ to four feet across, and three or 3½ feet wide. These furnaces have only one door, which is in the front of the furnace.

The charge of ore for a calciner, usually consists of three to three and a half tons. It is distributed equally over the bottom, which is made of fire bricks or square tiles. The fire is then gradually increased; so that towards the end of the process, which lasts twelve hours, the heat is as great as the ore will bear without being fused or baked together. The charge is then drawn out through holes in the bottom of the calciner, of which there is one opposite to each door, and, falling under the arch of the furnace, remains there till it is sufficiently cool to be removed. Water is, at this time, thrown over it to prevent the escape of the finer particles.

The calcined ore, which is black and powdery, is then delivered to the smelters, the charge of the melting furnaces is let down and spread over the bottom, the door of the furnace is put up and well luted. Some slags, from the fusion of the coarse metal or sulpheret, are added.

After the furnace is charged, the fire is made up, and the substances brought into fusion. When the ore is melted, the liquid mass is well stirred; and the substances being in perfect fusion, the smelter skims off, through the front door, the sand

or slags consisting of the earthy matters contained in the ore and any metallic oxides which may have been formed, which float on the surface. As soon as the metal in the furnace is freed from slags, the smelter lets down a second charge of ore, and proceeds with it in the same manner as with the first; and this he repeats until the metal collected in the bottom is as high as the furnace will admit of; without flowing out at the door which is usually three charges; he then opens the tapping-hole in the side of the furnace, and the metal flows into a pit filled with water. It thus becomes granulated.

The slags having been received in sand moulds, the blocks are broken, and any pieces found to contain particles of metal are remelted. Unless the slag is very thick and tenacious, the copper which they may contain is found at the bottom. What is clean or free of metal is rejected. The granulated metal usually contains about one-third of copper. When the ores are very stubborn or difficult to melt, fluor spar is added to the charge.

The calcination of the coarse metal, the product of the first fusion, is conducted in precisely a similar manner to the calcining of the ore. As it is now desirable to oxidize the iron the charge remains 24 hours in the furnace, and is repeatedly stirred and turned. The calcined metal is then melted with some slags from the last operations in the works, which contain some oxide of copper, as likewise pieces of furnace bottoms impregnated with metal, the proportion of each varying according to the stock or to the quality of the calcined metal.

The slags from this operation are skimmed off. They have a high specific gravity, and should be sharp, well melted, and free from metal in the body of the slag. These slags are melted with the ore, not only for the purpose of extracting the copper they may contain, but on account of their great fusibility, as being composed chiefly of the black oxide of iron, they fuse readily, and act as solvents. In some cases, the slags from the metal furnaces are melted in a distinct small furnace with some small coal or carbonaceous matter, and in this case the slags resulting therefrom are even sharper than those from the metal furnaces, they have a crystalline splendent appearance, and crystals are frequently to be observed in the interior.

The metal in the metal furnace, after the slag is skimmed off is either tapped into water, or into sand beds. In the granulated state it is called *fine metal;* in the solid form, *blue metal* from the colour of its surface. The former is practised when the metal is to be brought forward by calcination. Its produce

in fine copper is about sixty per cent. The calcination of the fine metal is performed in the same manner as that of the coarse metal.

The melting of the calcined fine metal is also performed in the same manner as the melting of the coarse metal; the resulting product is a coarse copper, every 100 parts of which, contain from 80 to 90 parts of pure metal.

The roasting is chiefly an oxidizing process. The pigs of coarse copper from the last process, are filled into the furnace, and exposed to the action of the air, the temperature is gradually increased to the melting point, and the expulsion of the volatile substances that remained is thus completed, and the iron or other metals still combined with the copper, are oxidized. The charge is from 25 to 30 cwt. The metal is fused towards the end of the operation, which is continued for 12 or 24 hours, according to the state of forwardness when filled into the furnace, and is let out into sand beds. The pigs are covered with black blisters, and the copper in this state, is known by the name of *blistered copper*. In the interior of the pigs, the metal has a porous honey-combed appearance, occasioned by the gas formed during the ebullution which takes place in the sand beds on tapping. It is in this state fit for the refinery, the copper being freed from nearly all the sulphur, iron, and other substances, with which it was combined.

Another mode of forwarding the metal for the refinery, still practised in some works, is by repeated roastings from the state of blue or fine metal; this, however, is a more tedious method of proceeding.

The refining furnace is similar in construction, to the melting furnaces, only the bottom is made of sand, and laid with an inclination to the front door; the refined copper being taken out in ladles from a pool formed in the bottom near the front door. The pigs from the roasters are filled into the furnace, through a large door in the side: the usual charge is from three to five tons. The heat at first is moderate, so as to complete the roasting or oxidizing process, should the copper not be quite fine. After the charge is run down, the slags are skimmed off; an assay is then taken out by the refiner with a small ladle, and broken in the vice, and from the general appearance of the metal in and out of the furnace, the state of the fire, and other circumstances, he judges whether the toughening process may be proceeded with, and can form some opinion as to the quantity of poles and charcoal that will be required to render it malleable, or to bring it to the proper pitch. The copper in this state is what is termed dry. It is brittle, is of a deep red colour, inclining to purple, an open grain, and a crystalline structure.

In the proeess of toughening, the surfaee of the metal in the furnace, is first well covered with charcoal. A pole, commonly of birch, is then held in the liquid metal, which causes considerable ebullition, owing to the evolution of gaseous matter; and this operation of poling is continued, adding occasionally fresh charcoal, until from the assays, whieh the refiner from time to time takes, he perceives the grain, which gradually beeomes finer, is perfectly closed, so as even to assume a silky, polished appearance in the assays when half cut through, and broken, and is become of a light red colour. He then makes farther trial of its malleability, by taking out a small quantity in a ladle, pouring it into an iron mould, and when set, beating it out, while hot, on the anvil, with a sledge hammer; if it is soft under the hammer, and does not craek at the edges, he is satisfied of its malleability, or as they term it, that it is in its proper plaee, and it is laded out into pots or moulds of the size required by the manufacturer. The usual size of the cakes for common purposes, is twelve inches wide by eighteen ineches in length.

The process of refining or toughening copper, is a delicat operation, requiring great care and attention on the part of the refiner, to keep the metal in the malleable state. Its surfac should be kept covered with charcoal, otherwise it will go back between the rounds of lading, the cakes being allowed to cool in the pot, and others laded thereon; in this ease, recourse must be had to fresh poling.

Over poling is to be guarded against, as the metal is rendered thereby even more brittle than when in the dry state. Its colour becomes a light yellowish red, its structure fibrous. When this is found to be the case, or, as they say, the metal is gone too far, the eharcoal is drawn off the surface of the metal, and the copper exposed to the action of the air, till it is brought back to its proper pitch.

Sometimes when eopper is difficult to refine, a few pounds of pig lead are added to the eharges of copper. The lead acts as a purifier, by assisting, on being oxidized itself, the oxidation of the iron, or any métal that may remain eombined with the copper. As the smallest portion of lead eombined with copper, renders the metal diffieult to piekle or clean from oxide in manufacturing, by hindering the scale or oxide from rising clean from the surface of the sheets, it must be carefully removed. Hence, the copper should be well rabbled, and exposed to the action of the air.

Copper for brass making is granulated that its surface may be increased, so as to combine more readily with the zinc, or calamine.

This is effected by pouring the metal into a large ladle pierced in the bottom

with holes, and supported over a cistern of water. The water may be either hot or cold. When warm, the copper assumes a round form, and is called *bean shot*. When a constant supply of cold water is kept up, the metal has a light ragged appearance, and is called *feathered shot*. The former is the state in which it is prepared for brass wire-making.

Another form into which copper is cast at the smelting houses, chiefly for exports to the East Indies, is in pieces of the length of six inches, and weighing about eight ounces each. These are called *Japan copper*. The copper is dropped from the moulds immediately on its becoming solid, into a cistern of cold water, and thus, by a slight oxidation of the metal, the sticks of copper acquire a rich red colour on the surface.

The other copper ores of England and Wales are smelted in a similar manner.

### *Solder for Copper.*

This is of two kinds, hard and soft.

Hard solder for copper, is usually made of eight pounds of brass, which is melted in a crucible, and a pound of spelter or zinc being heated in another pot, it is thrown into the melted brass, and the crucible covered. In about two minutes the melted metal is stirred, and poured upon a wet birch broom, placed over a pail of water, by which the solder is granulated, and being dried, is kept for use. This solder is very fusible, and yet bears the hammer very well.

When several pieces are to be successively soldered, one after the other, to the same vessel, it is necessary to use solders of different degrees of fusibility, to begin with that which is the easiest melted, and to proceed gradually to the others. For this purpose copper may be melted with various proportions of zinc, from three pounds to sixteen pounds of copper, to each pound of zinc. The more copper is used, the solder is the harder, and the less easily melted.

Soft solder for copper is made of two pounds of tin and one of lead, melted together.

### *Dutch Brass.*

The Commune of Stolberg, situated about six miles from Aix la Chapelle, is eminent for the manufacture of brass plates. The manufacturers consider the copper procured from Cornwall and from Drontheim, in Norway, as the best in quality.

The calamine which is used, is principally obtained from Vielle Montagne, near Aix la Chapelle, and from the territory of Cornelly Munster, near Stolberg.

The crucibles are made about fifteen inches in height, and an inch and a half in thickness. The furnaces in which the copper is smelted, are similar to the brass furnaces used in England, and placed on the ground; their mouth is upon a level with the floor of the workshop; and a deep trough is made below the flat pavement, to serve as a gallery to support the grate, and to admit a current of air to the ash-pit. The form of these furnaces is that of a cylinder, terminated by a narrow neck; they are 14 inches in height, 28 in width, and, at the aperture or summit, 14 or 15. During the operation they are covered with a plate of earth of the same materials with the crucibles.

Into each crucible is then introduced a mixture of the following materials; viz. 40 pounds of copper broken small, 65 pounds of calamine in fine powder, and double its measure of charcoal, also in fine powder. With this mixture the crucibles are filled and placed in two tiers, the one above the other; eight crucibles to each furnace. The crucibles being arranged as above described, a large fire of pit-coal is kept up for the space of twelve hours. The fuel is placed upon an iron grate at the distance of only 20 or 22 inches from that which supports the crucibles. After the fire has been kept up for twelve hours, the scum and charcoal is skimmed off, and a workman lays hold of each crucible with a pair of iron tongs, and throws it forcibly upon a bed of sand, in order to form a hole into which the matter is made to run.

The product of this first operation, is brass of a coarse, brittle, and unequal texture, called *arcost*, which must be subjected to a second fusion, in order to be rendered perfect. For this purpose the same crucibles are again employed. First there are thrown into each three handfuls of the mixture of charcoal and calamine, according to the proportions above mentioned. Over these are placed two or three pounds of brass clippings; then two more handfuls of the first mixture are introduced, together with a piece of arcost about a pound in weight, and these are finally covered with the first mentioned powder. The crucibles being charged in this manner, are placed in the furnaces, from which they are withdrawn after a space of two hours, in order to cast the metal into plates. These plates are cast with the aid of two blocks of very hard granite, five feet long, three and a half broad, and eight inches thick. These are placed one above the other; the upper block is raised by means of a pulley, in order to be washed and rubbed with cow-dung. It is heated before the casting of the metal. In order to give the plate the degree of thickness which is desired, hoops of iron, of different dimensions, are adapted to the inferior stone, which serve to confine the fused metal, and determine its thickness. The first stone is then replaced, and both receive the degree of inclination requisite for facilitating the entrance of the liquid. The plates which are made in this manner, vary in length, breadth, and thickness, from the sixth of a line to eight lines.

From this mixture are produced 53, 54, and sometimes 55 pounds of brass. The plates are exported to different countries, where they are used in the manufacture of clocks and watches.

Any old pieces of this Dutch brass is carefully sought after by our watch and clock makers, as it is not sold in our metal

warehouses. It was found by Doctor Thompson to consist of four parts, by weight, of copper, and one of zinc.

This brass is hammered into leaves, about five times as thick as gold leaf, namely, one-sixty-thousandth of an inch thick, and is sold under the name of Dutch gold, or Dutch metal: it is used for an imitation of gilding, but soon tarnishes, unless defended by varnish.

### *English Brass.*

Calamine is dug out of several mines in the west of England, as about Mendip, which lie about 20 feet deep. It is burnt or calcined in a kiln, or even made red hot; it is then ground to powder, and sifted into the fineness of flour, and mixed with ground charcoal, because the calamine, is apt to be clammy, to clod, and not so apt to incorporate.

About seven pounds of calamine are then put into a melting pot of about a gallon content, and about five pounds of bean shot copper uppermost; the calamine must be mixed with as much charcoal as will fill the pot. This is let down with tongs into a wind furnace, eight feet deep, where it remains eleven hours. They cast off not above twice in twenty-four hours, one furnace holds eight pots, disposed in a circle round a grate.

After melting it is cast into plates or lumps; 45 pounds of raw calamine produces 30 pounds burnt or calcined. Brass shruff serves instead of so much copper; but this cannot always be procured in quantities; because it is a collection of pieces of old brass, which is usually to be got only in small parcels.

The pale Bristol brass has been found, by Dr. Thompson, to consist of only two parts, by weight, of copper, and one of zinc.

Although the old process for making brass is still in use, yet some manufacturers use a portion of spelter or zinc, as well as its oxide, for cementing with the copper.

Spelter in ingots is taken and melted down in an iron pot; the melted spelter is then run through a ladle with holes in it, fixed over a tub of cold water; by which means the spelter is granulated or sholed, and is then fit for making brass. About fifty-four pounds of copper bean shot, ten pounds of calcined calamine, ground fine, and about one bushel of ground charcoal, are next mixed together. A handful of this mixture is put into a casting pot, and upon it, about three pounds of the sholed spelter. The pot is then filled up with the mixture;

and, in the same manner, eight other pots are filled. So that 54 pounds of copper shot, 27 pounds of sholed spelter, about ten pounds of calcined calamine, and about one bushel of ground charcoal, make a charge for one furnace, containing nine pots for making brass.

The pots being so filled, are respectively put into a furnace, and about twelve hours complete the process. From this charge, on an average, there is obtained 82 pounds of pure fine brass, fit for making ingots, or casting plates for making brass pin wire, or brass latten. This brass is of superior quality to the brass made from copper calamine, and is similar to the Dutch brass.

There are several other alloys of copper with zinc, in use; thus various alloys, known by the name of *Prince Rupert's metal*, *pinchbeck*, or *tombac*, are made by adding a pound of zinc to from three to ten pounds of copper.

Sometimes ready made brass is made instead of copper, as in the following instances.

*Spelter solder*, for brazing iron, copper, or other metals, is thus made:—

Three parts of pan-brass and one part of zinc are taken; the pan-brass is put into a crucible with a little borax. When the brass is melted, the zinc is put in, and the metal stirred with a wire, until nearly all the blue flame subsides; it is then poured out on a piece of sheet iron. To granulate it, it is heated in the fire, and struck on an anvil, which causes it to fall in pieces.

An alloy, called *Bath metal*, is made by adding nine pounds of zinc, to 32 of brass. And an extremely pale, nearly white metal, used by the button makers of Birmingham, under the name of *platina*, by adding five pounds of zinc to eight of brass.

The brothers Keller, who were famous statue founders, used an alloy, 10,000 parts of which contained 9140 of copper, 553 of spelter or zinc, 170 of tin, and 137 of lead. Their castings are excellent, although some are of very large size, as the equestrian statue of Louis XIV. cast at a single jet, by Baltazar Keller, in 1699; which is 21 feet high, and weighs 53,263 French pounds.

The equestrian statue of Louis XV. which was cast by M. Gor, at a single jet, is sixteen feet eight inches high, and weighs 60,000 pounds. Ten thousand parts of its metal contain 8245 of copper, 1030 of spelter, or zinc, 410 of tin, and 315 of lead.

These statues are usually called bronse statues. In an excellent publication, the Mechanics' Weekly Journal, the discontinuance of which is to be regret-

ed, may be found a curious account of the gross failures that have lately occurred in France, in casting several large works of this nature.

Cellini, in casting large works, advises the pipe conducting the metal from the furnace to the casting, to pass down to the lowest part of the cast, in order that as the metal rises, it may drive the air in the mould before it, and be less apt to make an imperfect cast.

Brass was well known to the Romans, under the name of orichalcum, who often took advantage of its resemblance to gold; and some sacrilegious characters could not resist the temptation of removing gold from temples and other public places, and chose to conceal their guilt by replacing it with orichalcum. It was thus that Julius Cæsar acted, when he robbed the capitol of 3000 pounds' weight of gold. He was followed by Vitellius, who despoiled the temples of their gifts and ornaments, and replaced them with this inferior metal.

The ancients do not appear to have used brass except for mere ornaments, to resemble gold. It is much more extensively employed by the moderns, and the alloy of copper with tin or bronse, is less extensively used;—because brass is cheaper than the alloy of copper with tin; it preserves its colour longer, and it is easier to work into various forms, especially for philosophical instruments; few of which were, probably, made by the ancients.

### *Solder for Brass.*

The hard solder for brass, is made by melting a pound of brass; and, according to the intended purpose, adding from one to six ounces of zinc previously heated.

The soft solder for brass, is made by melting six pounds of brass, adding first one pound of tin, and when that is melted, a pound of zinc previously heated. The solder is then stirred, and reduced to grains, by pouring it through a birch broom into water.

### *Gun Metal.*

The principal uses of the alloy of copper by tin, are to render copper less oxydable by water, or atmospheric air, to give hardness; to render it sonorous; to render it more fusible; to produce a close texture and whiteness for reflecting light, and to render copper less tough and dingy, or, as the workmen say, claggy.

Copper, alloyed with one of the smaller proportions of tin, by manufacturers, is the metal of which guns or cannon, improperly called brass guns, are made. Different proportions of these two metals are used at different manufactories; but this gun metal seldom contains less than one part of tin to nine of copper. Here as much strength, as is consistent with the preservation of the figure of the instrument during its use, is required; and, if more tin were added, the gun would be liable to be fractured by the explosion; and if less were added, it would be liable to be bent.

### *Ancient Tools.*

Copper alloyed with a somewhat larger proportion of tin than in gun metal in general, affords a metal sufficiently hard and strong for chopping tools, for many useful purposes. Of such proportions, namely, about eight or nine parts of copper, and one part of tin, there is very little doubt all the ancient nations who were acquainted with the alloys of copper by tin, generally made their axes, hatchets, spades, chisels, anvils, hammers, and other tools.

These metals united in these proportions, would afford the best substitutes known at this day for the instruments just mentioned, now commonly made of steel or iron. Accordingly, before the art of manufacturing malleable iron from cast iron was known at all, or, at least, practised extensively, that is, till within these last 400 or 500 years, the alloys of copper by tin, must have been very generally employed.

Celts have been found to contain, in perhaps most instances, the proportions of tin which renders them most fit for the uses to which they were applied. This proportion being considered to be about one part of tin to nine parts of copper.

## *Ancient Cutlery, and Kitchen Vessels.*

Copper, alloyed with a larger proportion of tin than is generally contained in ancient tools; that with one of tin to six or seven of copper, is fitter for cutting instruments, and piercing, boring, and drilling tools, than the metal of ancient tools, because it is harder, takes a finer edge, and yet is sufficiently strong on most occasions; nor do we possess at this day, as it is conceived, any metal which is so fit for knives, swords, daggers, spears, and drills, as this alloy, except iron and steel.

Saucepans, and other ancient cooking vessels, also were made of alloy of copper, by tin in the proportions last mentioned; as the old kitchen utensils were made of cast metal, the tin was added for the purpose of rendering the copper more fusible, and thus, also, for more easily casting of it into the required forms; the tin was also added to render the copper less readily oxydable, and for the colour of this composition. At present brass is preferred for kitchen mortars, and the skillets in which starch or milk is boiled.

From this it will be apparent that tin was infinitely more valuable to the ancients than it is to the moderns. Without this metal, it is not easy to conceive how they could have carried on the practice, and invented the greater part of the useful arts. Tin was even of more importance to the ancient than steel and iron are to the moderns; because alloys of copper by tin, would afford better substitutes for steel and iron, than any substitutes which the ancients in all probability could procure.

We see, also, the importance of Britain, in times more remote, probably than those of which we have any record or tradition; being probably the only country that furnished tin to the progress of cultivation; although the Periplus mentions the tin of Malacca.

If Mr. Locke had been acquainted with the properties of the alloys of copper of tin, and of their extensive use in highly advanced states of civilization among the ancients, he would have known that iron was not the only metal, by the use of which we are in possession of the useful arts, and he would not have said that it is past doubt, that were the use of iron lost among us, we should, in a few ages, be unavoidably reduced to the wants and ignorance of the ancient savage Americans.

Steel was got anciently from those ores only which yield it in a malleable state; as it is probably obtained at this day in India, and called woortz; and as it is also obtained in the northern Circars, and likewise by the Hottentots. As steel was the only state of iron anciently manufactured, it was too scarce, and much too dear for general use; and hence the extensive use of alloys of copper by tin, the best substitute for the malleable state of iron and steel.

## *Bell Metal.*

Copper, united with the proportions of tin last mentioned, is very sonorous; but it is rendered much more so by still larger proportions of tin. It is apprehended the sonorous property increases as the proportion of tin is increased, within certain limits; provided the alloy possess sufficient strength not to be

actured by the necessary impulse. But as the brittleness increases with the increased proportion of tin, not more than one art of tin is added to three parts of copper, to compose the ost sonorous metal that is manufactured, namely, bell metal. he proportion of tin varies in bell metal from one-third to one-fth of the weight of copper, according to the sound required, he size of the bell, and the impulse to be given. But the alloy ast mentioned is too brittle to be beat out into a plate for making trumpet; and, accordingly, an ancient lituus, which has been ade of hammered metal, was found by Dr. Pearson to contain nly about one part of tin and 7 parts ½ of copper. But M. arcet has discovered that bell metal, formed in the proportion f 783 parts of copper, united with 22 of tin, is, indeed, near-y as brittle as glass, when cast in a thin plate, or gong, yet, if is heated to a cherry red, and plunged into cold water, being eld between two plates of iron, that the plate may not bend, becomes malleable. He has manufactured gongs, cymbals, nd tom-toms, in this manner.

Sixty-four ounces of copper, with three of tin, forms a pale metal, ringing ery like sterling silver.

### *Ancient Statuary Metal, or Bronse.*

Copper is also united with tin for the purpose merely of becoming more fusible, and of continuing longer fluid, or cooling more slowly while passing from the melted, or fluid state, to the olid state. Such metal is used for making statues, and casts of gures in general, and is called statuary metal, and bronse. The roportions of the two metals are various, probably according o the colour proposed, and the size and figure of the cast, as vell as on account of the price of the metals.

The Greeks and Romans consumed vast quantities of copper n casts of figures. They added not only tin but lead to the opper. The proportions given by Pliny are one part of a mixure of equal quantities of lead and tin, to fifteen parts of cop-er. The use of the lead is not understood, if it was not to ave expense. The modern statue founders use a kind of brass n preference.

### *Bronse Medals.*

The superior malleability of copper has made the moderns prefer it in general for coins and medals; but the ancients preferred bronse, and as it resists the injuries of the weather and burial under ground, far better than pure copper, their coins and medals of this metal have come to our hands.

The bronse used for medals is first cast in moulds, and then

finished by the screw-press; hence, as copper does not melt thin enough to take a fine impression, there is a necessity for adding at least 5 parts of tin to 95 of copper, the tin, however, must not exceed 16 parts to 84 of copper; otherwise the extensibility of the copper is impaired. The finest medals are composed of 8 to 12 parts of tin united with 92 to 88 of copper. A little zinc is sometimes added, which causes the surface to acquire a fine green patina.

The dispute in what manner the ancient medals were struck has been the cause of some improvements in the arts.

Mongez, considering that the ancients were but little in the habit of using steel, maintained that their medals were struck with bronse dies, driven by the hammer upon heated blanks held by pincers.

The bronse dies used by Mongez were made of 22 to 26 parts of tin, added to 74 or 78 of copper. Some broke after striking 30 or 40 inch and half copper medals, from blanks; others struck 800 before they split; just as some steel dies crack the second or third time of using, while others will strike 14,000 or 22,000 medals without being injured.

Although copper medals could be thus struck from cold blanks by bronse dies, yet, in striking hot bronse blanks, the process did not succeed well, although better than when steel dies were used, as the heated bronse softened the steel so that the fine edges of the impression were speedily effaced, and the surface of the die was calcined and came off in scales. The proper degree of heat to be given to the bronse was very difficult to ascertain; at a brown red heat the impression was but faint, at a yellowish red the blank cracked on the edges. It was, however, found that bronse dies and punches are superior to steel when the object to be struck is necessarily heated, or when the die or punch itself is required to be hot.

The other party in the dispute affirmed that the ancient bronse medals were first cast and then finished by the die. In trying the necessary experiments to determine this point, it was found that the bronse, or brass, for a mixed metal of 107 parts of zinc with 892 of copper, was sometimes used, ought to be melted as quickly as possible, so that 10 pounds of metal should not take more than 12 or 15 minutes, and that the moulds should be so thin that the cast bronse may cool very quickly.

The greatest difficulty is the proper allowance for the contraction of the metal in cooling, when medals are to be copied from a pattern. Jeoffroy applied a thin leaf of lead to the pattern, and made it adhere by means of a burnisher. Puymaurin first tried to cover the pattern with several coats of varnish; but in the end he preferred to heat the pattern, to touch the

parts in relief with a pencil charged with melted bees'-wax, then apply on the wax moist paper of a proper thickness, and finally press the paper with a roll of wet linen. The pattern being thus enlarged in the proper proportion, is moulded in the common casting sand, which may be mixed with some fine powder of clay slate; but Chaudet prefers to mould such small articles in bone-ash. The channels between the main jet and each medal must be thin and wide, that the metal in them may cool before that in the proper moulds; as otherwise there would be danger that the main jet cooling and contracting, the metal might flow back through the side channels, and leave an imperfect impression. The moulds ought always to be smoked by a torch before the metal is run into them.

Mr. Artis, in his Roman Antiquities, has given a figure of a moulding frame, which he found, containing 62 coins of the Emperor Severus, who died at York, 4th February, 209. The whole has the appearance of an earthen bottle, there being two piles of 31 moulds each, with a main jet between them, and a short channel from the main jet to each mould. The neck of the bottle is formed into a funnel leading to the main jet.

The medals being cast, are finished by dies with a screw-press; as the relief is nearly complete, a very few strokes of the press is sufficient to finish them, and they do not require the heats that are required to be given to medals when struck from blanks, as in this case inch and half medals, even of pure copper, require 5 or 6 heatings, and 10 or 12 strokes; inch and $\frac{7}{8}$ medals, 7 or 8 heatings, and 14 or 16 strokes; 2 inch medals, 12 or 16 heatings, and 24 or 32 strokes; and 2 inch and $\frac{1}{2}$, or larger medals, 30 or 40 heatings, and from 90 to 120 strokes of the press.

## *Speculum Metal.*

The composition in common use which contains the greatest proportion of tin, is called speculum metal. The requisites of this metal are compactness, uniformity of texture, whiteness, sufficient strength to prevent its cracking in cooling, and to bear polishing without breaking.

Mudge found the whole of these properties attainable in the greatest degree by a little less than 1 part of tin with 2 parts of copper. But for very large instruments, such as the 40 feet telescope of Herschel, the proportion of tin must be less than in small instruments, on account of the brittleness.

Edwards affirms that different kinds of copper require different doses of tin to produce the most perfect whiteness. If the dose of tin be too small, which is the fault most easily remedied, the metal will be yellow; if it be too great, the metal will be

gray blue and dull. He first melts the metals together, and pours the alloy into cold water, to granulate it. Then melts the metal again, and casts the speculum with its face downwards, takes it out while red hot, and places it in hot wood-ashes to cool very gradually, as otherwise it would break.

Little first melts 4 parts of brass pin wire, with an equal weight of tin, and casts it into an ingot. He then melts 32 parts of the best bar copper, along with some black flux, and puts into it the ingot of brass and tin; when this is melted, he adds twelve parts and a half of tin, and, after that, a part and a quarter of white arsenic; the whole is then poured into cold water to granulate it, and again melted when the speculum is to be cast.

Some add silver to speculum metal, but Little found that it made the metal too soft, and hindered it from receiving the highest degree of polish, unless the compound metal was extremely brittle.

### *Whitened Copper, or False Silver.*

This metal may be formed by mixing white arsenic with any common oil, pearl-ash, and charcoal powder; and laying the mixture in alternate beds with granulated copper, in a covered crucible. A gentle heat is given at first, but afterwards it is raised quickly to the melting heat of copper; and as soon as the mixture is melted it is poured out.

A pound of copper, in bean shot, mixed with an ounce of neutral arsenical salt, a little borax, previously calcined, charcoal dust and glass in powder, being melted, also produce a white metal of this kind.

Or it may be made in a more direct manner by putting 10 parts of copper shreds into a crucible, along with one part or rather more, of regulus of arsenic, covering the crucible, and melting the whole together.

### *Pak Fong, or Chinese White Copper.*

This compound metal is smuggled in blocks of 10, 20, or 40 pounds, from China; 1000 parts of pak fong contain, according to the analysis of Dr. Fyfe, 400 of copper, 254 of zinc, 316 of nickel, and 26 of iron. It is, probably, a speiss obtained by smelting some ore, or mixture of ores. It is sold in China for about ¼ its weight in silver, and is strictly forbidden to be exported.

It has been confounded by some with tutenag, or zinc.

### *Violet Metal.*

This metal is made by melting together three pounds of copper shreds, with one of regulus of antimony. It is brittle, of a violet colour, and takes a very fine polish.

## *Gilt Copper.*

A metal composed of about six parts of copper, and one of brass, is the best for gilding, as copper does not readily take the amalgam, and from its colour requires more gold than when brass is added. A second coat of gilding is preferable to the same quantity of gold laid on at once.

The amalgam of gold used in gilding, contains about two parts of quicksilver, with one of gold.

The copper to be gilt, is first cleansed by dipping it in a mixture of aqua fortis, with four times, or more, as much water. Large articles are first heated, then dipped in a strong solution of sal enixum, or sal ammoniac, and then in the weak aqua fortis. The surface being thus pickled, is cleansed by a brush wheel of brass wire; or for very fine work, by a hand brush.

That the amalgam may spread equally over the surface of the copper, it is first dipped in a solution of quicksilver in aqua fortis, and then the amalgam is applied with a piece of flattened copper wire, which is occasionally dipped in the solution of quicksilver, and then the amalgam touched with it, and the small quantity taken up rubbed over the article.

Another method is to mix the amalgam with more quicksilver, and some acid, and to dip the article into the mixture.

The gold being thus spread evenly over the surface of the copper, the quicksilver is evaporated by a gentle heat, the article being exposed over a small stove, under a chimney having the front built up, and closed with a window sash, so that the workman may see how the work goes on, without being exposed to the fumes of the quicksilver. The articles if large, are held in pincers, or if small, a number are put into an iron pan, or cast pot; and when sufficiently heated, the larger articles are rubbed with a soft bristle brush, and the smaller articles are shaken in a bag, and well stirred about with a brush. As the gilt metal has still a dull appearance, it is polished by rubbing it with a wire brush with small beer, or ale grounds.

The colour of the gilt copper is heightened by heating it afresh; and if any spots appear of a different colour, they are touched with a stick dipped in aqua fortis. It is then thrown into very weak aqua fortis, which will cause any spots where the gold is deficient to appear. The gilt copper is again polished with the scratch brush; and if a very high polish is required, burnished with a blood-stone and water.

If a very high colour is required, the work is covered with *gilders' wax*, composed of eight ounces of bees' wax, and three each of red chalk, or red ochre, and of calcined verdi-

gris, with an ounce of dried borax; and being held over the fire till the wax smokes, and is ready to take fire, it is then dipped in water, and the wax cleaned off with the wire brush and beer.

For a still higher colour, the work is afterwards spread over with a paste composed of equal parts of sal ammoniac; saltpetre, blue vitriol, and a half part of crystallized verdigris, made up with water, and then heated till it smokes; after which it is treated as with the gilders' wax.

Dead yellow gilding, presenting a frosted surface, without any polish, and of a beautiful yellow colour, is produced by a saline preparation formed of six ounces of saltpetre, two of copperas, and one each of white vitriol and of verdigris. The work being covered with this paste, is thrown into weakened aqua fortis, and the ebullition produces the dead or matted appearance.

The following alloys of copper are used at Birmingham for gilding upon. Four parts of copper, melted with one of Bristol, or pale yellow brass, and then remelted with 14 ounces of tin to each pound of copper that was used. For common articles, 3 parts of copper, 1 of Bristol brass, and 4 ounces of tin, to each pound of copper. If the articles are to be highly polished, half the tin is taken away, and supplied by regulus of antimony. If the articles are wished to be of a pale colour, half or even two-thirds only of the copper may be put in. Compound metals, nearly the colour of gold coin, which of course require but little gold for gilding, are made by melting 2 parts of Cheadle, or dark brass, 1 of copper, with a little Bristol brass, and a quarter of an ounce of tin, to each pound of copper, or 16 parts of tough cake copper, are melted with 5 of spelter or zinc.

### *Plating of Copper with Gold.*

Ingots of copper or brass, are plated with gold for the purpose of rolling out into sheets, by first cleansing the surface of the copper, then placing a piece of gold upon it; hammering it out to cover the surface; binding it on with wire that it may not slip; soldering the edge of the gold plate with silver filings, mixed with borax, by exposing the ingot to a sufficient heat; the ingot may then be rolled out into sheets.

### *Cold Gilding of Copper or Brass.*

For cold gilding by friction, a fine linen rag is steeped in a saturated solution of gold, till it has entirely imbibed the liquor; this rag is then dried over a fire, and afterwards burned

) tinder. Now, when any thing is to be gilded, it must be reviously well burnished; a piece of cork is then to be dipped rst into a solution of salt in water, and afterwards into the lack powder, and the piece, after it is burnished, rubbed ith it.

### *Grecian Gilding of Copper or Brass.*

For this gilding, equal parts of sal ammoniac and corrosive ublimate are dissolved in spirit of nitre, and a solution of the old made with this menstruum. Upon this the solution is omewhat concentrated; and the metal is put into it, or brushed ver with it. The surface of the metal is rendered quite black y the liquor; but on being exposed to a red heat, it assumes he appearance of gilding.

### *Plating of Copper with Silver.*

The ingot of copper is first filed, and its surface left rough; he rolled silver is annealed, pickled in weakened spirit of salt, lanished and cut to fit the surface of the copper ingot, which s dipped in a solution of borax, and strewed with powdered orax before the silver is applied, which is then bound on the opper with wire; and on being exposed to a sufficient heat, he metals unite, and the plated copper may be rolled out into heets.

Copper may also be plated by merely burnishing silver leaf pon it, while it is hot; this inferior kind of plating is called *French plating.*

In cutting out the rolled plated metal into pieces of the required forms and izes, there are many shreds or scraps unfit for any purpose but the recovery of the metals by separating them from each other. For this purpose wo modes were practised: one by melting the whole of the mixed metals with ead, and separating them by sweating, and cuppelling. The second, by dissolving both metals in oil of vitriol with the help of heat, and by separating he sulphate of copper by dissolving it in water, from the sulphate of silver, vhich is afterwards to be reduced and purified.

The method invented by Mr. Kier, is now commonly practised by the manufacturers in Birmingham, and is more easily executed than any of the other nethods. The pieces of plated metal are put into an earthen glazed pan; ome oil of vitriol, mixed with one-eighth or one-tenth its weight of saltpetre s poured upon them, and they are stirred about that the surfaces may be frequently exposed to fresh liquor, and the action is assisted by a gentle heat. When the liquor is nearly saturated, the silver is to be precipitated from it by ommon salt, which forms a precipitate easily reducible by melting it in a crucible with a sufficient quantity of pearl-ash, and, lastly, by refining the melted ilver, if necessary, with a little saltpetre thrown upon it. In this manner he silver may be obtained sufficiently pure, and the copper will remain unhanged.

Otherwise the silver may be thrown down in its metallic state, by adding to he solution of silver, when poured off clear, a few of the pieces of copper, nd a sufficient quantity of water to enable the liquor to act upon the copper.

### *Silvered Copper or Brass.*

Copper may be silvered over by rubbing it with the following powder; two drams of tartar, the same quantity of common salt, and half a dram of alum, are mixed with fifteen or twenty grains of silver precipitated from its solution in aqua fortis by copper, and then brushed off and polished.

Silvering by fire is performed in the following manner: half an ounce of silver, common salt and sal ammoniac, of each two ounces, and one dram of corrosive sublimate are triturated together, and made into a paste with water. With this, copper utensils of every kind that have been previously boiled for a short time with tartar and alum, are rubbed; after which they are made red hot and polished. In this manner is done the cheap silvering of the saddler and harness-makers. The above mentioned precipitate of silver may also be laid on another way with borax or mercury, and made to adhere by fusion.

### *Tinned Copper.*

Copper is tinned by scraping the surface, heating the plate sprinkling a little resin and sal ammoniac upon it, pouring some melted tin, or a mixture of tin and lead upon the copper, and spreading it evenly over the surface by means of a many folded cloth.

Copper is tinned for the purpose of defending it from the action of the acids and fats used in cooking.

The doubts which have been raised for years past respecting the wholesomeness of tinned copper, and those to which the accidents occasioned by glazed pottery have given birth, caused an alarm to society to be created by morbid sensibility, and many fancied remedies have been proposed for the imaginary evil.

Maloiun, in 1742, proposed to employ spelter or zinc for this purpose; but he and his followers forgot that although zinc is harder than tin, yet it is still more easily attacked and dissolved by acids.

Of late the French have begun to tin their copper vessels with tin hardened by iron. For this purpose, they melt together eight pounds of tin, and one of iron turnings, or small nails, in a crucible; adding a handful of salt, or of pounded glass, to keep the air from the metals while they are melting.

Rinman for the same purpose has proposed several cheap enamels, for lining copper and iron vessels, mostly composed of fluor spar, gypsum, and common glass in various proportions.

## *White Brass Pins.*

The operation of whitening may be performed by several different acids; but the acids usually preferred are white and red argol, or cream of tartar.

First, after the heads are cast upon the shafts, the quantity of pins intended to be whitened at once, generally about 50 pounds, are put into a colander; and this is dipped into a mixture of about one gallon of oil of vitriol, to six gallons of water, and the pins lie in the same mixture about half an hour, and the acid that hangs about them is removed by dipping the same vessels into clean water two or three times.

After this, about 25 pounds of pins are put into a common scouring barrel, and along with them about 50 pounds of small grain tin, six ounces of red argol, and three gallons of warm water, and being turned for one hour, they will be perfectly clean.

They are then dipped into a mixture of about one pound of blue vitriol, in two gallons of cold water. This gives the pins a complete cast of copper.

After this operation a layer of about six pounds of pins, dipped as above, are laid at the bottom of a copper boiler, and at the top of them, a layer of about seven or eight pounds of fine grain tin, rather small, and so on, first the one and then the other, until the whole 50 pounds of pins are put into the copper boiler. At the top a covering half an inch thick, of the small grain tin is laid, except that upon one side a small opening is left to enable the workman to introduce water to the bottom of the vessel, without disturbing the tin at the top. A sufficient quantity of cold water is poured into the copper vessel to fill it, or nearly, and next a quantity of small grain tin, to fill up the small opening left in the vessel as above mentioned.

When the water becomes a little warm, there is put into it by a dredging box, four ounces of red or white argol, or four ounces of cream of tartar, pounded fine, and it is boiled an hour. Then the tin and pins are thrown together in cold water, and the pins separated from the tin by a colander. This operation is repeated until the colour of the pins is perfect, they are then dried off in warm bran.

## *Blue Vitriol.*

Blue vitriol, when manufactured, is made by heating plates of copper red hot in an oven, the oxide that is formed on their surface is beat off, and this repeated until the whole of the cop-

per is reduced to oxide. The oxide is boiled in oil of vitriol, and when the dissolution is completed, boiling water is added, and the blue liquid run off into leaden vessels, and left to crystallize by gradual cooling.

The waters that run through copper mines become impregnated with this salt, and are sometimes boiled down and crystallized; but in general it is found most advantageous to throw old iron into the water, which separates the copper and is dissolved in its place.

Blue vitriol is used to bronze iron, and to prepare several blue and green colours.

Blue vitriol is the sulphas cupricus cum aqua of Berzelius, or Cu: S:+10 Aq. equal to 3,126,380. Dr. Thomson estimates the sulphate of copper as Cu. S: +5 Aq. equal to 15,625.

## *Blue Verditer.*

The greatest part of this is made by dividing 240 quarts of boiling blue vitriol water at 35 deg. Baumé, or sp. gr. 1·299, in four open tubs, and adding 180 quarts of boiling muriate of lime water, at 40 deg. Baumé, or sp. gr. 1·357. The mixed liquors are to be well stirred together, and then left for 12 hours to settle. A portion of the clear liquor is then divided into two parts, and examined by adding blue vitriol water to the one, and muriate of lime water to the other, whether the mutual change in the liquors is complete; if not, the deficient liquor must be added, observing that there is less inconvenience in a small excess of blue vitriol than of muriate of lime.

The clear liquor is then to be drawn off, and there is poured upon the settling of sulphate of lime the second washings of a former operation, at 8 or 10 deg. Baumé; the whole is stirred, then left for 12 hours to settle, and the clear liquor poured off and added to the former.

The settling is then thrown upon hempen-cloth strainers, and washed with the last washings of a former process and water, until the liquid that passes is not more than 3 deg. Baumé. The last washings are set by for washing the settling of future processes. There is obtained by this means about 670 quarts of green liquor at 20 deg. Baumé.

Two cwt. of quicklime are in the mean time slaked by adding 60 gallons of water; and the whole first passed through a wire sieve, and then ground fine in a stone mill. A cwt. and quarter, or half, of this cream of lime is added to the above green liquor, the whole well stirred, and then left to settle. The clear liquor is examined, and if ammonia water added to it produce a full blue colour, more of the cream of lime must be added, until the trial by ammonia water produces only a

ale blue tinge. The settling is then put upon linen filters nd washed first with the washings of former operations, and hen with water, until the liquid becomes weaker than two leg. Baumé. The liquid that runs through, and is 10 deg. Baumé, is boiled down to 40 deg., and the muriate of lime rystallized for future processes; that liquor which is weaker han 10 deg. is also reserved for future use. By this means here is obtained about half a ton of wet green; 100 parts of vhich generally contain 27 of dry colour, as may be ascertained by drying a small portion.

A quarter cwt. of this wet green, more or less, according to ts content of dry colour, is put into a deal trough, two pounds of cream of lime added, the whole quickly stirred together; a pint and a half of pearl ash-water, at 15 deg. Baumé, is then poured in, the whole ground as quickly as possible in a mill.

Two saline solutions are in the mean time prepared. One of half a pound of gray, or Egyptian sal ammoniac, in a gallon of water; the other of a pound of blue vitriol, also in a gallon of water. The colour, as soon as it is ground, is put into a stone bottle, the blue vitriol water is first added, and immediately afterwards the sal ammoniac water; the bottle is then corked, well shaken, and rosined; 24 of these bottles are usually prepared as a day's work.

At the end of four days four of these bottles are emptied into a brandy cask holding about 100 gallons, and this is filled up to within a few inches of the bung hole with clear water. The mixture is well stirred, and a cock being placed so as to leave about one-third of the cask for the settlings, the water is drawn off, and replaced with fresh, once a day in winter, and twice a day in summer; a fresh stirring being given each time, and the bung hole kept covered. The colour is washed in this manner until the liquor drawn off does not change the yellow colour of paper stained with turmeric to a green, which generally happens after 8 or 10 washings. Each cask produces nearly a cwt. of superfine wet blue verditer, which is used in large quantity by the paper-hanging manufacturers.

A colour of inferior quality, called fine blue verditer, is prepared by putting in an additional pound of lime, and using white or European sal ammoniac; and another still inferior, called blue, No. 1, by using four pounds of lime instead of two, and a pound of sal ammoniac instead of half a pound.

The superfine blue, and fine blue, are also prepared as lump colours by drying the wet paste in the shade.

### *Refiners' Verditer.*

The refiners prepare verditer from the bluish green liquid left

on separating silver from its solution in aqua fortis, by putting the solution into large wooden bowls lined with pitch, along with great plenty of water, and slips of copper. Dr. Merrett says they put a cwt. of whiting into a tub, pour the copper liquor upon it, and stir it every day, till the liquor loses its colour. The liquor is then poured off, and fresh added; this is repeated until the whiting has obtained the proper colour; the clear liquor poured off is boiled down and used instead of saltpetre for making aqua fortis. Dr. Lewis says this process is very uncertain, and that even the most experienced workmen frequently fail entirely, or produce a green colour instead of a blue; it succeeds best when the liquor is warmed before it is poured on the whiting.

Mr. Pelletier advises to mix powdered lime with the nitric solution of copper, taking care not to put so much lime as to alter the whole of the nitrous liquor, then to wash the settling, and grind it with lime in the proportion of an ounce or ounce and half of lime to each pound of the settling.

### *Rough Verdigris.*

This is manufactured by the farmers' wives and daughters near Montpellier, in France, to supply themselves with pocket money.

The copper used is about one-twenty-fourth of an inch thick cut into pieces about five inches long, three wide, and weighing about four ounces each; it is well hammered, to prevent it coming off in scales, when the greened surface is scraped.

Grape stalks, and weak wine, were formerly used to cotton the copper; but at present they use only the cake left after pressing the grapes, which was then flung on the dunghill. This cake is kept until a leisure time occurs, by pressing it very close in casks; when used, it is taken out and aired by placing it very loosely in casks, or in earthenware pans, covered with straw caps. It heats and exhales an acid odour; if the heat grows too violent, the cake is taken out and cooled, by spreading it abroad: sometimes in cold weather it does not heat kindly, but grows putrid, and is spoiled.

After three days' heating a trial is made, by burying a copper plate in the cake for 24 hours, whether the cake cottons the copper properly; if not, a fresh trial is made. When the cake is in proper train, the copper plates to be changed into verdigris are heated, so that they can scarcely be taken hold of by the hand, and placed in layers along with the cake, in earthen pans, the bottom and top layers being made of cake, and left for a fortnight or three weeks. If there were any copper plates left from a former operation, the verdigris upon them is carefully washed

ff, and they are dried; as otherwise, the verdigris left on them would become black.

When the cake becomes white it is time to empty the pans, nd by this time the surface of the copper is covered with loose ilky crystals. These plates, when taken out, are placed upight upon sticks in a cellar, supported one by the other, and afer two or three days they are dipped in water and replaced for bout a week, when they are dipped again into water, and this s repeated weekly for six or eight weeks.

Every 30 or 40 pounds of copper yields five or six pounds of he moist fresh rough verdigris, which is now scraped off the lates with a knife, and packed either in large wooden boxes, r in small white leather bags, about a foot each way. That acked in the bags is exposed to the sun until it becomes so dry s not to allow a knife to enter it: by this drying it loses about alf its weight.

The copper plates are sometimes totally changed into rough verdigris in a couple of seasons; at other times they will take ine or ten seasons.

The boxes of fresh moist verdigris are sold for making crystallized verdigris.

Verdigris is also manufactured at Grenoble.

Verdigris is either of a blue or green colour. Blue verdigris contains 4334 parts of peroxide of copper, 2745 of acetic acid, and 2921 of water; 2345 of which last was driven off by drying in the heat of boiling water. The green verdigris contains about 44 parts of peroxide of copper, 32 of acetic acid, and 24 of water; of which last, 10 were driven off by a heat of only 140 degrees. Berzelius considers them, from the ease with which they are changed by a slight heat, or the addition of either cold or hot water into other salts of copper, as $C\cdot\cdot A^{-2} + Cu\cdot\cdot Aq.^2 + 10$ Aq.; but Thomson, as $Cu\cdot\cdot {}^2A\!\!-\!\!+ 6$ Aq. only, equal to 23,000.

## *Crystallized Verdigris.*

This salt is also frequently called *French Verdigris.* It is manufactured by dissolving as much moist fresh rough verdigris in distilled vinegar, as the acid will take up by boiling. When saturated, the solution is poured off clear into another copper boiler, and evaporated until ready for crystallization.

A number of sticks, a foot long, are split crosswise at one end, to within two inches of their other end; the four branches are kept wide open by small sticks. These sticks are hung by threads to bars placed across the top of the boiler, so that the crystals may adhere to them, by which means there are formed conical masses of crystals, weighing five or six pounds each.

It takes about three pounds of moist rough verdigris to make a pound of crystallized verdigris.

The principal use of this verdigris is as a show-toy in the windows of dr gists and colourmen's shops; it is also used to make a wash-colour for maps, to make the spirit of verdigris for smelling bottles.

This, the acetas cupricus cum aqua of Berzelius, he considers as Cu: $A^2$ + Aq. or 2,511,900: and Thomson, as Cu·A— + Aq. or 12,375.

## *Vert de Mitis, Schweinfurt Green, or Vienna Green.*

Dissolve 1lb. of verdigris in vinegar; dissolve also 1lb. of white arsenic in sufficient quantity of water; pour the solution of arsenic into that of the verdigris; if a dull green sediment falls, more vinegar must be added, until the sediment is dissolved. The liquor is then to be boiled, and after some time very fine green crystals fall down: when they do not seem any longer to increase they are to be separated, washed with cold water, and dried.

This colour has a bluish tinge, but it may be prepared of a deeper shade, and of a yellow tinge, by dissolving 1lb. of common potash in a sufficient quantity of water; then 10lb. of the paint, prepared as above described, is to be added and the mixture gently heated, by which means the colour gradually changes to a yellowish tint. If it be boiled too long, however, the paint acquires a colour similar to that of Scheele's green, but it is always a superior article.

In the preparation of the original paint, the liquor poured off the green crystalline grains must be differently treated according to its nature, which varies according to circumstances. If the liquor still contains much copper, some arsenic liquor must be added; if the liquor contains an excess of arsenic, some fresh solution of verdigris is to be added, and the process carried on as before. Sometimes there is an excess of vinegar, and in that case it may be employed along with some fresh vinegar, to dissolve a fresh parcel of verdigris. In like manner, the liquor left in the preparation of the yellowish green paint, may be used in the preparation of Scheele's green.

## *Lime Acetate of Copper.*

This is prepared by Mr. Ramsay, of Glasgow, for the calico printers. It is a fine deep blue salt, which is soluble in water, and when kept for some time the crystals become spotted with white crusts of acetate of lime.

The manner in which he prepares it, is unknown; but Dr. Thomson found 2775 parts of it to contain 975 of acetate of lime, 1125 of acetate of copper and 675 of water; hence, he considers it as Ca·A— + Cu: A— + 6 Aq.

## *Scheele's Green*

Is made by dissolving two pounds of blue vitriol in three gallons of boiling water, and also two pounds of pearl-ash, and eleven ounces of white arsenic, in another gallon of water, filtering the two solutions, and adding the solution of blue vitriol to the other by degrees while hot, and washing the sediment with cold water.

Other green colours, of various shades, may be made by dissolving blue vitriol in water, along with Epsom salt, alum, or copperas, in various proportions, and pouring pearl-ash water into the solution as long as any sediment falls down: the liquor is then to be strained, and the sediment to be washed.

## [*Nitrate of Copper.*

This salt is considerably used by the calico printers. One hundred pounds of single aqua fortis will dissolve ten and a half

pounds of copper, and make one hundred and three pounds of a solution of nitrate of copper at 64° Tweedale's hydrometer, which is the strength generally adopted by the printers, either for a verdigris green, (Scheele's green,) or the *resist paste.* To make the crystallized nitrate, double aqua fortis should be employed, adding the shreds of copper as fast as the effervescence will permit. The water bath is then employed for farther evaporation.]

### TOUGH IRON, OR MALLEABLE IRON.

This very useful metal, is sold in England of various qualities, and in various forms, suited to the uses to be made of it.

Swedish iron, all of which is manufactured with fir charcoal, and preserves its superiority over every other kind.

English wrought iron, mostly manufactured with coke, and of inferior quality.

No. 2 iron, is a better kind of English iron.

No. 3 iron, is the best kind of English iron.

In regard to the most usual forms in which tough iron is sold, they are sheets of various breadths and thicknesses. Bars, usually ten feet long, and from six inches wide, and three-quarters of an inch thick, down to one inch and a half wide, and nine-sixteenths of an inch thick; squares and bolts, or rods, of the same length, from three inches thick down to half an inch. Wire from seven-sixteenths of an inch, down to the smallest that can be drawn.

Tough iron being manufactured from pig iron, it is necessary to exhibit the manufacture of pig iron, although it is a compound metal, before that of the simple tough iron, its principal ingredient.

Four methods are in ordinary use for smelting iron ores. 1. The Catalan forge; 2. The single block furnace, or German *stueck oven;* 3. The flowing furnace, or German *floss oven;* and 4. The high furnace, worked either with charcoal or coke.

The propriety of employing one or other of these methods of smelting iron ores, depends entirely upon local circumstances, and the capital that can be employed.

Tough iron is also either *perfectly malleable iron,* both hot and cold, as the Swedish iron, and the best kind of English iron, finished by the tilting hammer at the refinery. 2. *Hot short iron,* which works well when cold, but is brittle and untractable when hot. 3. *Cold short iron* does not work well when cold, but is very malleable when heated.

### *Charcoal Pig Iron.*

The single block furnace, or stuck oven, is the smallest furnace used in manufacturing charcoal pig iron. The fire room is ten or fifteen feet high. This fire room is either conical or egg-shaped.

Experience having taught the workmen in the Catalan forges, that there was some advantage in heightening the sides of the forge, in order to concentrate the heat, and smelt more ore at a time; the iron masters followed up the practice, and thus produced these furnaces, which have only two openings at their lower part. One of these openings is the twyer, by which the blast is admitted, the pipe of which is inclined towards the bottom of the crucible of the furnace; and the other opening is an eye, through which the slags run out as soon as the crucible is sufficiently filled; and when metal begins to flow by the same opening, thus showing that the crucible is full, the operation is finished, and the fire is blown out.

As the side walls of this furnace are too deep to allow the pasty mass of smelted iron to be taken out by the mouth at top, and there is no opening at the lower part for that purpose, there is a necessity for breaking down one of the side walls to get out the iron. Until 1762, these furnaces were used throughout Styria to smelt sparry iron ore, and brown oxide of iron of that country, and some are still at work.

In smelting iron ore in the furnace, the blast pipe is first placed; this is usually made of clay spread upon a wooden mould, and is moveable so that it may be raised up as the crucible fills, even to two feet and a half, above the bottom. The eye is then arranged, so that it may be raised gradually, and the hole in the wall, by which the iron was taken out, is built up.

The furnace is then filled to one-third its height with charcoal, and the fire lighted. About six cubic feet, or half a cwt. of charcoal, with a little ore, is then added occasionally, until the furnace is filled. The bellows are then set gently to work, and after five or six hours' firing, the furnace is usually sufficiently hot to allow the full charge of ore, namely, one cwt. of brown oxide with each charge of charcoal. These charges are continued for ten or twelve hours, and then the fire is blown out, and the wall broken down to get out the iron.

During the smelting, the blast pipe is moved two or three times; and the eye raised up as often, to allow more room for the metal below it. The mass of metal weighs about 15 or 20 cwt.; and from 3 to 6 cwt. runs out at the eye with the slags.

The iron yielded by these furnaces is very pure, and indeed half refined; the produce is about 35 parts in 100 of the washed brown oxide. The refining is finished on a small forge hearth, in which it loses one-tenth of its weight. To obtain one cwt. of iron, 25 cubic feet, or 2¼ cwt. of charcoal of resinous wood, and the refining of 1 cwt. of this iron into thick bars, 1½ of

harcoal. So that for obtaining 100 pounds of bar iron, 415 ounds of charcoal are required in the whole.

Sparry iron ore, mixed with brown oxide of iron, yields 25 ounds of raw iron from 100 of ore, and consumes 3½ cwt., r 36 cubic feet of charcoal of mixed wood; so that to obtain 00 pounds of bar iron, 538 pounds of charcoal are required in he whole.

Pig iron is now seldom made in this manner, and few of hese furnaces are in blast in any country.

In these kinds of iron-smelting furnaces, which are called y the Germans *floss ofen*, and sometimes *blau ofen*, or *chuer ofen*, the fire room is from 15 to 25 feet in height, with swelling out a little below half its height, as in the boshes of he high furnace. Towards the bottom of the fire room is an ye or hole, and sometimes two, one above the other, to let ut the metal and slags; but which are kept closed, with an ron plug coated with clay, except at the time when the fur- ace is to be emptied. In consequence of this convenient node of extracting the metal, the fire is kept up for months ogether.

A charge for these furnaces is usually 9½ cubic feet of char- oal of soft wood, and 1⅓ cwt. of prepared ore, generally parry iron ore, or brown hæmatites. The furnace being rought into heat, 100 of these charges are flung in every 4 hours. At the end of every 20 charges, the lower eye is pened, and the metal allowed to run out; the usual produce is 2 cwt. each piercing, or 420 cwt. weekly, sometimes it mounts to 500 cwt. The slags being partly removed from he surface of the metal, a little water is sprinkled upon it; nd by this means it is obtained in thin cakes, which are taken ff as fast as they are formed.

There are also made between each running two openings of he upper eye hole, by which means a great part of the slag is ot rid of.

The iron yielded by these furnaces, is cast or pig iron, and s distinguished into two kinds.

1. *Soft metal;* bluish externally, but white, granulated, and pongy when broken. It runs slowly from the furnace, ac- ompanied with blackish or bluish slags, containing a large roportion of metallic grains. This soft metal is the best for efining speedily into tough iron, and is obtained when the uantity of charcoal used is the least that can be employed, nd the furnace is not very high.

2. *Hard metal;* white, or grayish white externally, and ery brilliant when broken. It runs quickly from the furnace, ises in thin cakes, and the slags are generally whitish. In re-

fining, it forms steel; unless previously exposed to the blast, heated under a fire of small charcoal, but not brought to melt. This metal is obtained when the smelting is performed with more charcoal than is necessary, and the furnace is tall.

These furnaces are esteemed the best for smelting sparry and hæmatitical iron ores, particularly when it is intended to manufacture natural steel, rather than either cast or tough iron.

The greatest part, however, of pig iron, is smelted in high furnaces.

The four figures here given, exhibit the principal vertical and horizontal sections of the high furnace of Elend, in which iron is smelted by means of charcoal.

Fig. 177, is a vertical section, in the direction *a*, *b*, of fig. 180.
Fig. 178, is another vertical section, in the direction *c*, *d*, of fig. 180.
Fig. 179, is a horizontal section, taken at the height *i*, *k*, of fig. 177.
Fig 180, is a horizontal section, taken at the height, *l*, *m*, of fig. 177.

In these figures, *a*, is the fire room, which is in this instance 28 feet high, and octagonal, but in many furnaces square. *B*, is the mouth or top, by which the furnace is charged, 3½ feet over, surrounded by a brick wall, *c*. *D*, is the internal lining, of very refractory sand-stone. *E*, is the external lining, or chemise, formed of clay mixed with small stones or slags. *F*, is the main mass of the furnace, or mantle; it is solidly built of gray wacke stone, connected by cement, and bound together by iron bars. *G*, is the twyer arch, by which the blast pipes pass to the interior of the furnace. *H*, is the tymp arch, by which the furnace is tapped, and the metal run out. *I*, are thick iron bars some supporting the two linings of the fire room, and others preventing their bulging at bottom. *K*, are strong bars of tough iron, built in the main mass of the furnace at different heights, with large keys at each end, to prevent the walls from bulging or cracking. *L*, are channels of tiles, made in the masonry, to allow the moisture of the stone to evaporate and disperse. *N*, is the twyer hole. *O*, is the dam-plate, of cast iron, over which the slags run out when the crucible or hearth of the furnace is full. *P*, is a cast-iron plate, serving to support the dam-plate. *Q*, is another cast-iron plate, supporting the roof of the twyer hole. *R*, are the cheeks or sides of the tymp. *U*, are walls, or battlements surrounding the mouth of the furnace. *V*, is the flooring, on which the workmen stand when charging the furnace. *W*, is the bottom of the fire room, on which bottom is constructed the crucible or hearth, on a bed of sand closely packed together. *X*, is a gutter in the floor of the workshop, along which the metal runs when the furnace is tapped. *Y*, are two stones, which close the fire room at bottom.

The main mass of this furnace, with its linings, serves for years; but the crucible, which is three feet deep, and two feet wide at bottom, being made of blocks of sand-stone, is gradually dissolved by the iron, so that the fire is seldom kept in for more than forty weeks, and then let out, in order to repair this part. *Z*, is a single block of stone, forming the back of the crucible. 1, 2, 3, are the stones on the twyer side of the crucible. 4, 5, 6, are the stones of the crucible, opposite to the blast hole. 7, are the stones forming the sides of the tymp. 8, are the stones of the fore part of the crucible. 9, is a strong iron bar, called the tymp, which supports the eye, or opening into the crucible. 10, are the stones, forming the dam over which the slags run.

These dam stones occupy the whole breadth at the bottom of the hearth, excepting about six inches; which, when the

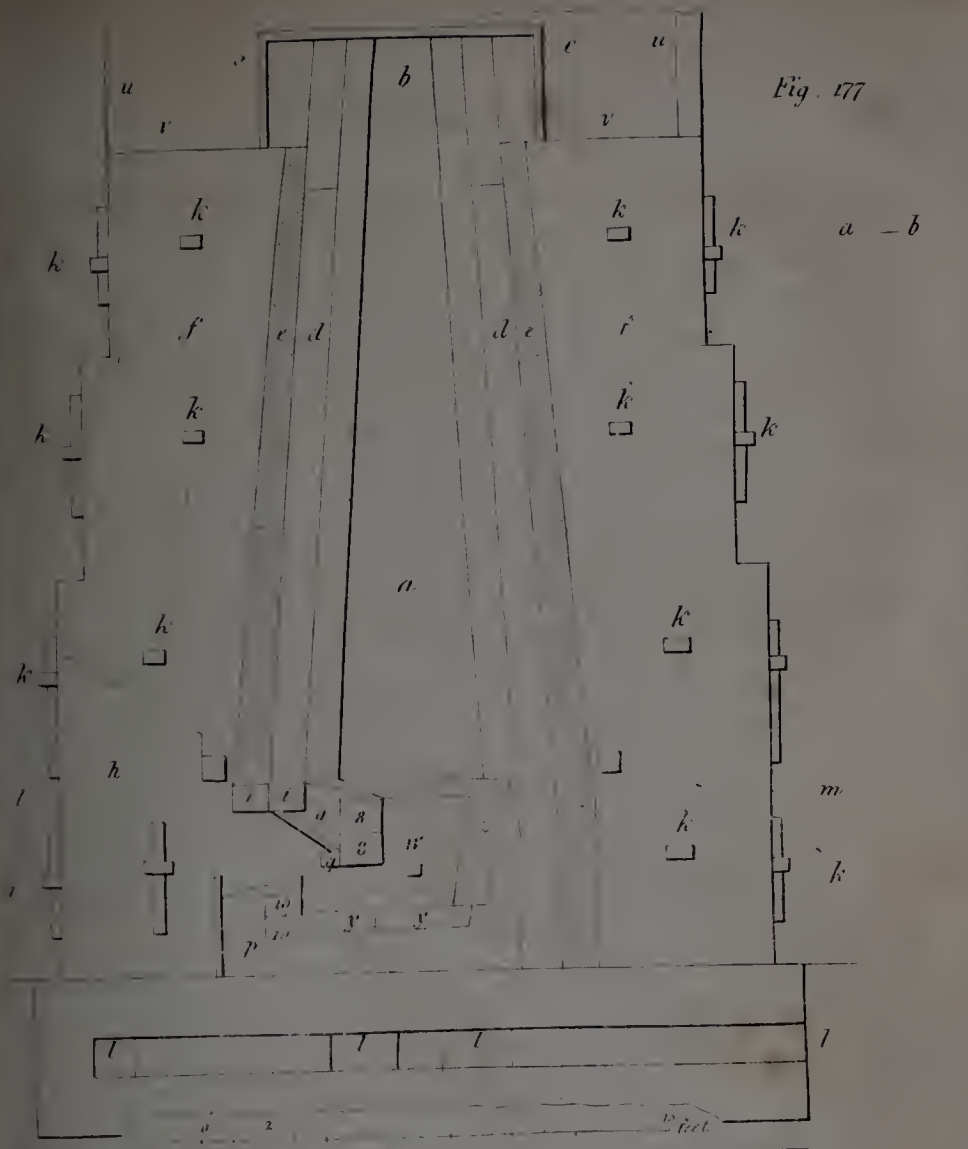


Fig. 177
a — b
a
b
c
d
e
f
g
h
i
k
l
m
u
v
w
x
y
p
Feet

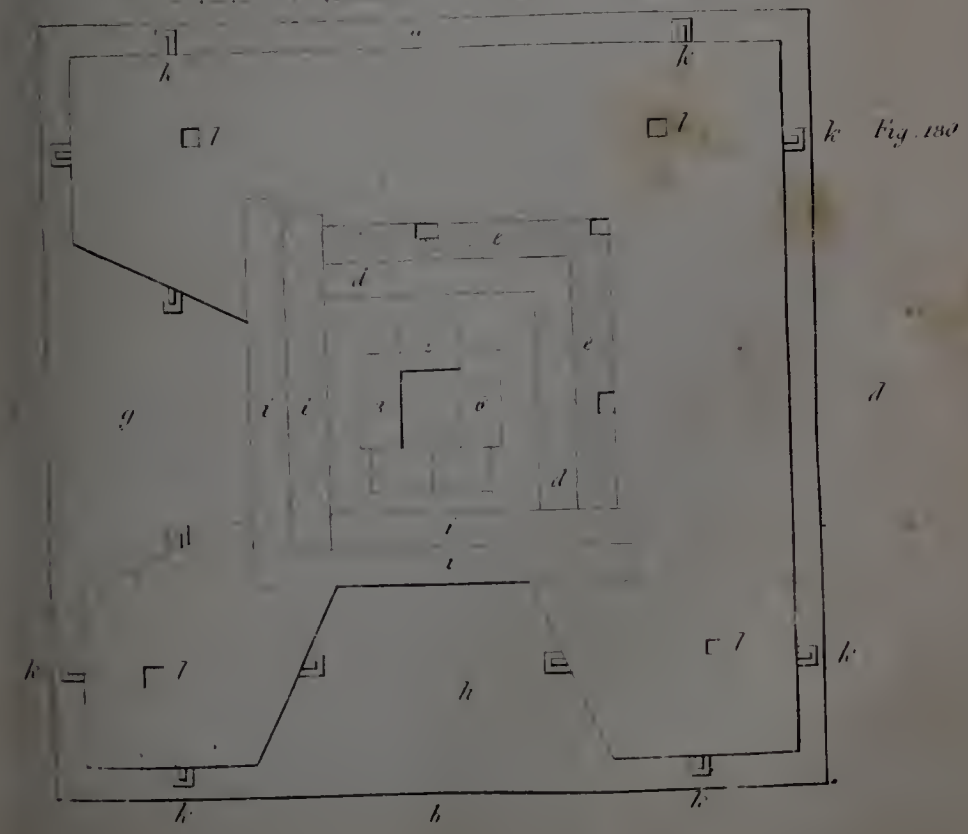


Fig. 180
a
d
e
g
h
i
k
l

Fig 178

c – d

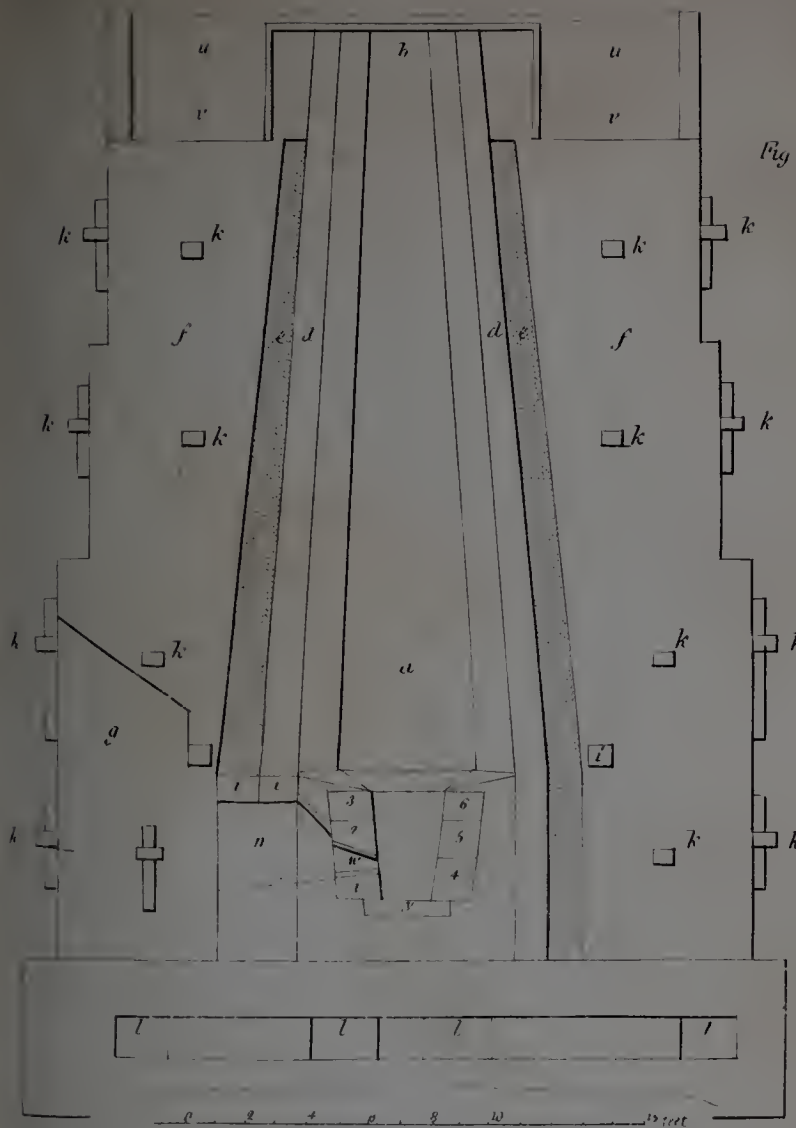
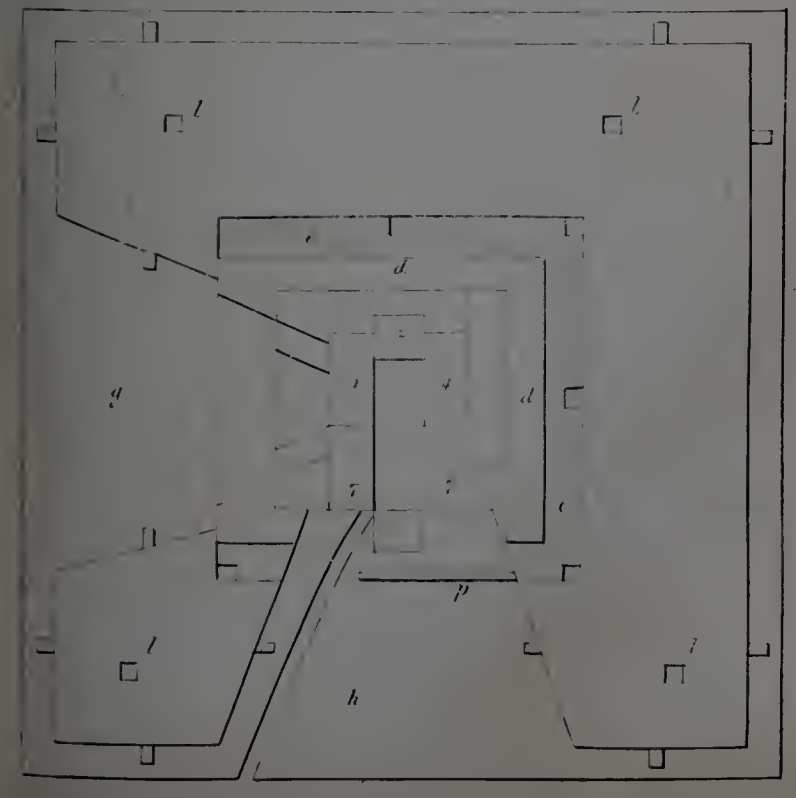



Fig. 179



furnace is at work, is filled every cast with a strong binding sand, which is broken through when the metal is run out. The top of the dam stone, or rather the notch of the dam plate, is from four to eight inches lower than the twyer hole. The space under the tymp plate, for five or six inches down, is also rammed every cast, full of strong loamy earth, and sometimes even with fine clay; this is called the tymp stopping.

11, is the twyer, to receive the blast pipe.

In all these furnaces, the blast pipe is furnished with several nosles, or nose pipes, from two to four inches diameter, which are screwed on, according as the furnace is deemed to require an alteration in the volume, or density of the blast.

12, are the inclined planes, called boshes, forming the top of the crucible, and supporting the charge of ore and charcoal; the fire-room being seven feet wide. In some furnaces of this kind, the crucible is not so much contracted as in this furnace.

The French and German high charcoal iron furnaces, seldom exceed 30 feet in height; the ores yield scarcely one half their weight of metal, and as the blowing machines are usually only wooden bellows, the furnace seldom yields more than 200 or 300 cwt. of east-iron in a week, at the expense of 1 cwt. seven-tenths of charcoal for each cwt. of metal.

In Sweden, the furnaces of this kind are usually about 35 feet high; the internal part above the boshes is a very long ellipsoid, whose smallest diameter of 8 feet, is placed horizontally 14 feet above the bottom of the crucible. A furnace of this kind, but only 30 feet high, blown with leather bellows, in which clay iron-stone was mostly smelted, 106 cwt. of iron was produced every 24 hours, or 742 cwt. by the week: 130 pounds ·6 of charcoal, were consumed for every 100 pounds of iron produced.

At Newjansk, in Siberia, a furnace of this kind has been built, in which the crucible is 7 feet high, the swelling of the boshes occupy nearly the same height, above which is a truncated cone, 21 feet in height, ending at top in a cylinder of 6 feet high; so that the whole height of the fire-room is 41 feet. The diameter at the bottom of the crucible is 2 feet ½; at the top, 4 feet ½; at the boshes, 13 feet; and at the mouth, 6 feet. The blast hole is 2 feet above the bottom of the crucible, and the blast is given by four cylindrical machines. In this furnace, a mixture of about one-third of hæmatites, with two-thirds of common magnetic iron ore, is usually smelted; and it is said to yield 404 cwt. of iron every 24 hours, or 2826 cwt. by the week; and only 115 pounds of charcoal are consumed in pro-

ducing 100 pounds of iron. It must be remarked, that the ore is very rich, as 100 parts of it yield 62 of metal; and this may in some measure explain the great produce of this furnace.

A great number of experiments were made in Styria, from 1762 to 1780, to ascertain the comparative advantages of three kinds of furnaces in smelting sparry iron ore; and it was found, that for producing a cwt. of cast-iron, there were consumed on an average in flowing furnaces, 1 cwt. ½ of charcoal of resinous wood; in high furnaces, 2 cwt. one-twelfth; and in single block furnaces, 3 cwt. one-eighth.

At Schleyden, not far from Roer, the iron is made to undergo a commencement of refining in the high furnace, by the blast being directed upon the metal while it remains in the crucible or hearth of the furnace. When the metal is run out, it is covered with charcoal dust, and sprinkled with water. The refining of this pig iron is afterwards completed by the Walloon method.

Of late years, coke has been used extensively in England, for smelting iron ores; particularly the clay iron ore, which lies in beds between the coal itself. As these furnaces are usually blown by machines moved by steam engines, these iron works can be established in places where there is no stream of water. Coke requiring a stronger blast than charcoal to excite a great heat, it is very usual to have two blast holes.

Fig. 181, represents the vertical section of a coke high furnace at Koenigshutte, in Silesia; and fig. 182, is the plan of the same. In these figures, *e*, is the internal lining of the fire-room, which is 50 feet high, and 12 feet wide at the boshes, while the crucible is only 2 feet wide, and 8 feet high. *G*, are the archways of the twyer or blast-pipe. *H*, is the archway of the tymp. *I*, are strong iron bars to support the main mass of the furnace, over the archways of the two twyers and the tymp. *K*, are strong iron hoops, which bind the furnace, and prevent its bulging or cracking. *V*, is the mouth of the furnace; *x*, is the trough to convey the metal to the moulds when the furnace is tapped and *y*, are the cast-iron pipes, by which the blast is conveyed from the blowing machine to the twyers, which are not placed exactly opposite to each other.

In the smelting house where this furnace is used, the ore is a mixture of about 72 parts of brown iron stone, and 28 of common clay iron stone, to which are added about 20 of limestone; 100 of the mixed ore produce about 33 of cast-iron. The blast used, is 1220 cubic feet of air by the minute, with a pressure of five feet of water. The furnace is generally worked for 40 weeks, and then requires the fire to be blown out in order to repair the crucible. The average produce is 423 cwt. of iron by the week; each 100 pounds of which require the consumption of 308 pounds of ore; 243 pounds ·8 of coke weighing 31 pounds ·4 by the cubic foot, and 68 pounds of limestone.

In a work at Gravenhorst, where meadow iron ore is smelted, the height of the furnace is 36 feet, its breadth at the boshes, 9 feet, ¼, and the weekly produce of iron, is 225 cwt. of cast-iron, every 100 pounds of which requires the consumption of 290 pounds ·8 of ore, 69 pounds of limestone, and 417 pounds ·5 of coke.

At Creusot, in France, furnaces of about 40 feet in height are used; the boshes, which are at one-third the height, are 10 feet wide; the blast is 1250 cubic feet of air by the minute. The ore is iron ore in grains, mixed with clayey and calcareous ores in beds. 100 parts of the mixed ore yield only 20 or 22 of cast-iron; every 100 pounds of which, consumes 250 pounds of coke for its production; no flux is used.

In England, where the consumption of cast-iron is far greater than in any other nation, the greater part is smelted with coke; although some charcoal furnaces are still in blast, for producing the best iron. The crucible, or hearth, of the English furnaces, is lined with bricks made of very refractory clay, and as this lining is more durable than the sand stone used on the Continent, the furnaces are kept constantly in blast, sometimes for ten years or more.

In Glamorganshire, the furnaces are from 50 to 65 feet high. The ore is the clay iron stone of the coal mines, and is mixed with an equal weight of coke, and a quarter its weight of limestone. 100 parts of ore, yield about 38 of cast-iron; and each furnace yields weekly about 910 cwt. of metal.

In Shropshire and Staffordshire, the furnaces are not so high as those of Glamorganshire. The ore, which is the same, yields about one-third of cast-iron; 100 pounds of which, require about 350 pounds of coke, to produce it, and each furnace yields about 770 cwt. of metal weekly.

A furnace of Mr. Walker's, near Sheffield, is 47 feet high, and is charged in the course of every 24 hours, with 360 cubic feet of coke, 45 of the hæmatitical iron ore of Cumberland, 22½ of Yorkshire clay iron-stone, and 22½ of limestone. The weekly produce is 420 cwt. of metal fit for iron guns, so that each cwt. of that metal requires 2 cwt. of coke for its production; and the mixed ores yield one-third of their weight of metal.

At Wisbey Low-Moor works, are four furnaces, 38, 42, 42, and 50 feet high; those of 42 feet, are in a slight degree the best. The furnaces are circular; the crucible, 6 feet high, and 2 wide; the boshes, 11 feet wide, and just in the mid-height between the top of the crucible and the mouth of the furnace, which is 4 feet across. The blast, in the 50 feet furnace, which has two twyers, is 3000 cubic feet by the minute; the other fur-

naces have only one twyer. A charge is composed of 960 pounds of ore, 460 of coke, and 320 of limestone; 50 charges are flung in every 24 hours, and the weekly produce of cast-iron is 700 cwt.: so that 230 pounds of coke are consumed in producing 100 pounds of cast-iron; and 100 parts of the ore yield 21 of metal.

The furnaces at the Clyde iron works, near Glasgow, are 31 feet high; the fire-room is square; the blast is 350 cubic feet of air by the minute, with a pressure of 8 feet of water. The ore is the kidney-iron ore, found in a bed of clay; the coal that is coked is pyritous and clayey. The charge for 24 hours is 300 cwt. of ore, 90 cwt. of limestone, and 600 cwt. of coke: the average weekly produce is 700 cwt. of metal.

With a view of defying the effects of expansion in splitting the furnace, a rock has, in one instance, been excavated, about 50 feet deep, and lined with fire-bricks; but on letting on the blast, the rock opened 4 or 6 inches from top to bottom.

There are, indeed, so many circumstances to be considered in building these large furnaces, that the chance of their cracking is very great. 100 parts of sandstone, if taken fresh from the quarry, contains from 8 to 12 of water; so that supposing the shell of the furnace contains 1200 tons of stone, it will contain on an average 120 tons of moisture; and even if bricks are used, the great proportion of cement that is necessary, will introduce as much moisture. The evaporation of this great mass of moisture, requires the drying of the furnace to be continued for two or three months before the blast is let on; many are indeed blown earlier, from an anxiety to get a return for the great capital necessarily expended.

When coke was introduced as the fuel for smelting iron, and the blowing machinery was but weak, the ore required to remain in contact with the ignited fuel for a long time, in order to compensate for the deficient temperature of these furnaces, in comparison of those worked with charcoal. This suggested an increase of the height of the blast furnace, and hence the height of furnaces were increased from the 18 or 20 feet, which were the usual height of charcoal furnaces in England, to 40, 50, 60; and in Wales, one was built 70 feet in height. In this last case, the strength of the blast was scarcely sufficient to render any flame visible at the top of the furnace. After a vain endeavour to ignite the immense body of fuel contained in the furnace, the height of it was reduced 30 feet by cutting a hole in the side, narrowing the mouth, and throwing in the charge at the height of 40 feet: this was attended with success.

When blowing machines, worked by steam engines, were applied to these furnaces, the quantity of air sent through the fire, and the strength of the blast could be increased to any extent, and it was soon discovered that by increasing the temperature, the same union of the carbonaceous matter of the fuel with the iron, could be produced by 30 hours' contact, as by 4 days' contact in a less temperature.

The consequence of this discovery, has been a general predilection in favour of small furnaces; and thus the observations of the iron masters in England coincide with the experiments already mentioned in p. 506, to have been made in Styria, respecting the superiority of the flowing furnace above the high furnace.

The state of the air, by which the blast is supplied, has been found to be of much consequence in these large furnaces. The quantity of iron that a furnace will yield weekly, in summer, is frequently only the half of what it will yield in winter. A variation in the moisture of the air, also affects both the quantity and quality of the iron; and hence the use of the hydraulic regulator, i

hich the strength of the blast is determined by the pressure of a column of ater, has been in many instances abandoned.

The appearance of the slag or cinder is the criterion for showing the work- g order of the furnace, and the quality of the iron. When the cinder as- mes a greenish yellow colour, it is not so favourable an appearance as the ue tint, which is sometimes almost as vivid as ultra-marine, and is generally ccompanied with colourless cinder. When the furnace is in very bad condi- on, the cinder is green, so dark as to be almost black, and is very fusible on ccount of its containing a very large proportion of oxide of iron that has es- aped reduction in its passage through the furnace.

The appearance of the metal that runs from the furnace, hen the stopping between the dam stones and the side of the rnace is tapped, will show when too much coke is used; for a substance resembling black lead, and called *kish*, floats in ny considerable quantity upon the metal, it shows that the rnace will bear the proportion of ore to the coke to be in- reased.

The produce of the coke furnaces are divided into three inds: (No. 1, iron, called also kishey iron, as being covered ith kish; gray metal; smooth-faced metal; and black cast on. This is esteemed the best cast-iron, and fit for casting.

No. 2 iron, called motley iron, and mottled iron.

No. 3 iron, called also white cast-iron, and forge pig; as eing principally destined to the finery forge.

Mr. Mushet has used the blast furnace for refining iron as ell as smelting it. He prefers indeed to make the furnace, hen intended for this purpose, rather smaller than is now sual; namely, not more than 20 or 30 feet in height, 6 or feet diameter at the boshes or widest part, 2 or 3 feet diame- er at the top; having a square or cylindric hearth or crucible, or 6 feet high, and $2\frac{1}{2}$ to 4 feet in diameter.

The materials used, except the coke or other fuel, are to be roken so as to pass through sieves or riddles, whose openings lo not exceed three quarters of an inch.

The various charges he uses, after the furnace has been pro- erly heated, vary according to local and commercial circum- stances, and are mixtures of iron-ore or iron-stone, with coke slags, scoria, cinder, or lime, with or without pig or cast-iron, n various proportions.

In smelting, the metal in the hearth of the furnace is to be protected from the blast by a body of scoria, to the depth of 15 or 18 inches, or even more; no part of which should be al- lowed to flow or run off (as is the case in the common method of smelting,) until the furnace is tapped. The scoria, if the operation has been well conducted, will be of a greenish co- lour, and rather transparent, and it is convenient to allow it to form a covering over the metal, in the box or moulds.

If, after the first or second tapping, the metal is not found to

be high enough blown, or decarburetted, the proportion of coke &c. is to be gradually reduced, or that of the ore or slags, with a proportional quantity of lime, or other flux, increased, until the metal is of a proper quality for the paddling furnace or stamping fire.

In the smelting of 600 pounds of pig iron, with 180 of slags 100 to 150 of limestone, and 300 to 400 of coke, there are generally obtained 24 or 25 cwt. of finers' metal, from each ton of pig iron.

This method of smelting may be applied to the manufacture of pig or cast iron, by keeping the surface of the metal in the hearth, protected by a sufficient depth of slag, and by drawing off the metal from below the slag, instead of allowing the last to flow off above. This mode of making pig iron requires a less powerful blast than the common method; and ores of a richer quality may be used in the furnace, than can be reduced with advantage in the usual mode of making pig or cast iron.

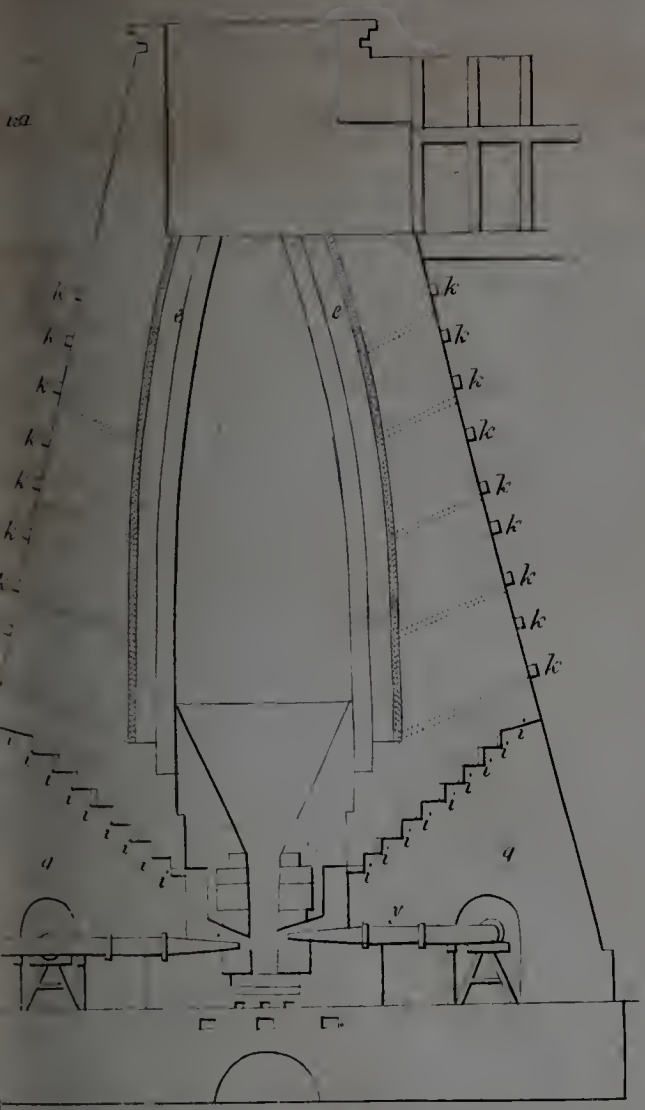
## *Foundery of Pig Iron.*

For the purpose of melting cast iron in small quantities, for the purpose of moulding delicate objects, which require the iron to be in a very fluid state, the Berlin foundery uses the following blast furnace; the metal used is obtained in Silesia, and the castings of this foundery are much esteemed for their workmanship.

Fig. 183, represents the external appearance of the furnace, which is an oblong rectangular prism, five feet high, three feet and a half wide, and cased entirely with cast iron plates screwed together. Fig. 184, is the vertical section, in the direction *b*, *d*, in fig. 187. Fig. 185, is a cast iron plate, which forms the bottom of the furnace, and by which the upright plates, *c*, which form the sides of the furnaces, are kept in their places; a slit, *h*, *e*, and the two holes that are near it, render this connexion easy to be established. A somewhat similar plate forms the top of the furnace, and retains the upper ends of the side plates in their places. Fig. 186, is the plan, taken a little above the twyer, as in fig. 185.

In all these figures, *a* is the lining of the furnace, composed of refractory brick work. *B*, a lining of unfusible sand, well packed together. *C*, plates of cast iron, forming the external sheathing of the furnace. *D*, is an eye-hole which is occasionally opened to let the melted metal run into the moulds. *E f*, is the bottom plate of the furnace, set upon a low mass of brick work. The top plate has a large round hole, through which the furnace is charged with coke and metal. *H*, is a hole made in the bottom plate, above which is made a bed of unfusible sand. *I*, is a cast iron twyer, to receive the nosle of the blower cylinders.

The fusion of 30 cwt., of 132 pounds each, or nearly two tons of iron in this furnace, lasts in all nine hours, and consumes 65 cubic feet, or 15 cwt. of good coke. The first three hours are employed in heating the furnace gradually, the blast is then let on, and the furnace charged with metal. One hundred pounds of metal generally produces 93 of very fine cast work, so that 7 pounds of iron are lost.



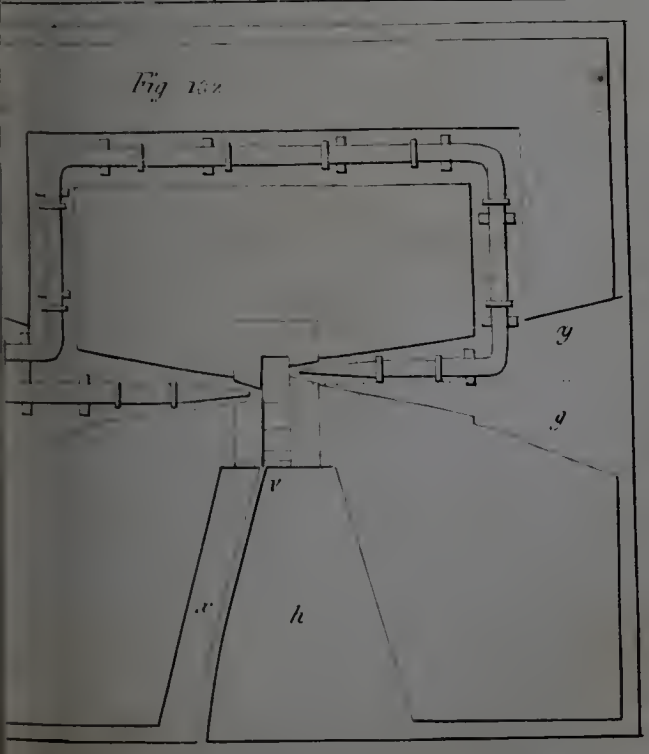




Fig 182

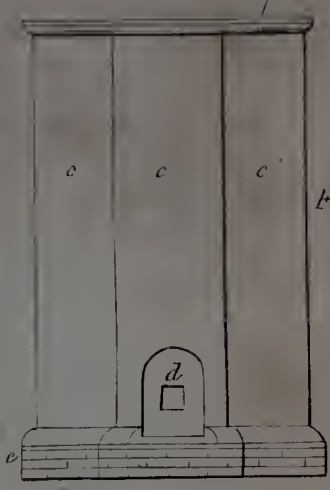



Fig. 183.

Fig 184

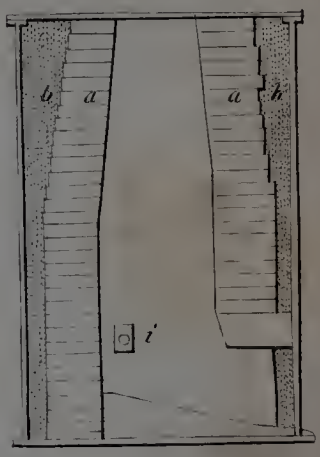


Fig. 185.

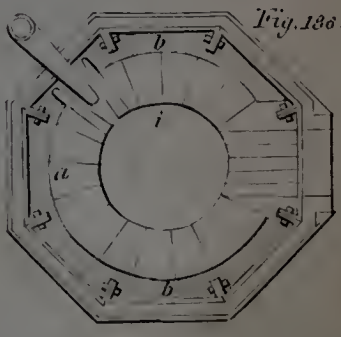



Fig. 186.

*Fig. 187.*

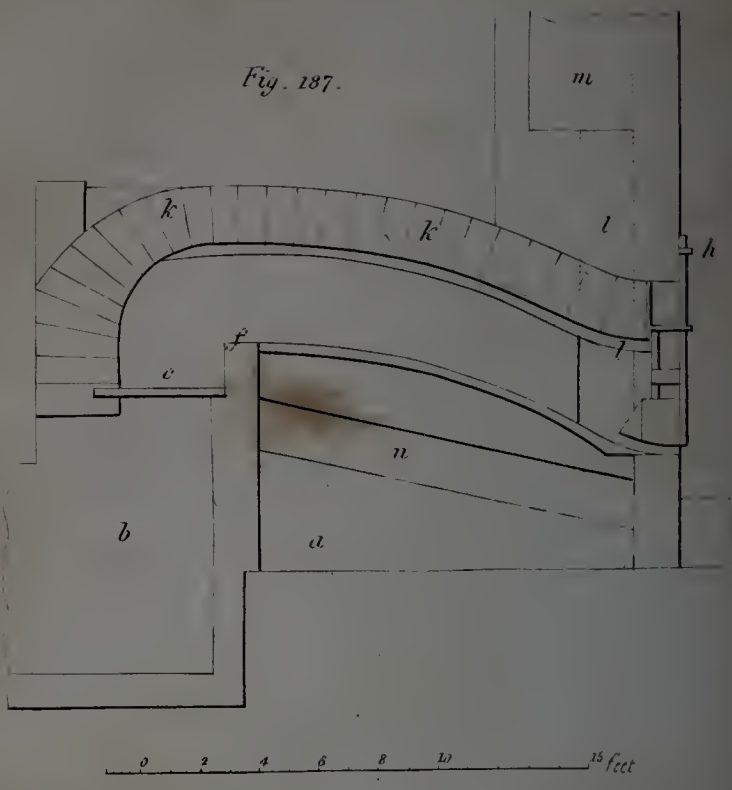
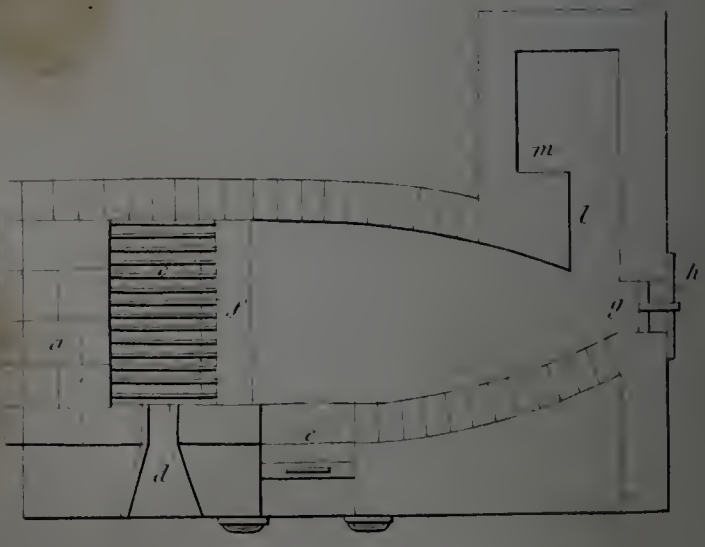



*Fig. 188*



For smelting cast iron in larger quantities at a time, namely, or 60 cwt. reverberatory furnaces are usually employed.

Fig. 187, represents the vertical section of these reverberatories, in the direction of the line *a, g;* and fig. 188, is the plan of the same, on the level of the dge. *A*, is the main mass of the furnace. *B*, is the ash-room, which is made y large. *C*, is the grate, formed of iron bars. *D*, is the fire-room door. *E*, he door into the chamber, by which the furnace is charged with the iron to smelted. *F*, is the bridge between the fire-room and chamber, over which flame passes. *G*, is another opening into the chamber, by which the charge en melted may be taken out in ladles; this opening is shut by means of an n door lined with clay, which is prevented from opening when the furnace nighly charged with iron, by iron bars, *h*, running through staples driven into furnace. *I*, is the eye of the furnace, usually kept close with a plug, which withdrawn when the whole melted metal is to be run out at once into the ulds. *K*, is the arched roof of the fire-room and chamber, inclining downrds towards the vent, in order to direct the flame upon the charge in the mber. *L*, is the vent, which communicates with the chimney, *m*, built serate from the furnace, and carried about 35 feet at least above the level of vent. *N*, is the gutter, left in the brick work under the bed of the chamr, to hasten the drying of the furnace.

Fifty cwt. of cast iron may be conveniently melted on the d of this furnace, in three or four hours, by means of 70 cuc feet, or 34 cwt. of raw pit coal, if the weather is cold; but warm weather more fuel is required. In this melting, each vt. of iron loses about 10 or 12 pounds of its weight; notwithanding the bed of the chamber is made of clay mixed with arcoal or coal dust.

A series of experiments, made at the royal foundery at Ber-, have shown that 100 cubic feet of raw pit coal produce the me effect as 475 cubic feet of beech wood.

Cast iron run into sand moulds is soft, and when turned in a the, the turnings will be even one-sixth of an inch thick; but the iron is run into cold thick cast iron ingot moulds, the elted metal is so much chilled that the surface becomes quite ard, and when turned in a lathe, the turnings are not larger an very fine needles.

It is very difficult to cast good hard iron rollers; for if not fficiently hardened at the surface, and to a proper depth, they ill not wear well: and if they are hardened to the very cene, they often crack across the middle, and become useless.

For very small castings of only a few pounds, the blue meltg pots made of Stourbridge clay and coke powdered, are used, nd the melting performed in a common wind furnace. Some unders use American potash as a flux, and thus produce a mel which has considerable elasticity and toughness; so that it ay be used for nails, and even table forks.

The Chinese iron founders use a still smaller apparatus; for e Guignes, in his Voy. a Peking, ii. 169, says:—

In China, the founders traverse the streets to mend the cast iron po[illegible], work in the open streets. The crucibles in which they melt iron are an [illegible] in diameter, of refractory clay. One workman receives the melted iro[illegible] moistened paper, and conducts it into the cracks and holes, while an[illegible] spreads and joins it with a humid rag. The furnace itself is four inches br[illegible] and eight long, it contains several crucibles, which are covered with a st[illegible] order to concentrate the heat. The workman's box is six inches broad, six[illegible] long, and eighteen high. It is divided into two portions, the upper part c[illegible] tains the necessary apparatus; the lower is the bellows, composed of a d[illegible] phragm exactly fitting the hollow in the box, and which can be moved by n[illegible] of a handle formed of two small iron bars. The fore and hind part of th[illegible] are furnished with valves, and there are two others which open into a sm[illegible] channel that runs along the outside, and having in the middle of the box a pip[illegible] When the workman draws the piston to him, the valve behind opens, and th[illegible] in front shuts, so that while the wind is forced into the small channel, the h[illegible] part of the bellows is filling with wind. This kind of bellows yields a go[illegible] blast, and does not fatigue the workman.

## *Charcoal made tough Iron.*

The Catalan forges are the most simple apparatus for obtai[illegible] ing tough iron, even directly, from its ores; they produce ex[illegible] cellent iron, and require only a small capital to establish them[illegible] On the other hand, they expend a considerably greater propo[illegible] tion of charcoal than the other kinds of furnaces; each furna[illegible] supplies only a small quantity of iron weekly, and this iron[illegible] either tough iron or steel, not the common cast iron as furnish[illegible] by the flowing and high furnaces.

The section of the Catalan forge is represented in fig. 189, and its plan[illegible] fig. 190; the cavity, *c*, is generally sixteen inches square, and about two f[illegible] deep. The sides, *r*, *k*, *v*, of the cavity, for about eighteen inches deep, a[illegible] lined with cast iron plates, and the remainder is filled up with charcoal r[illegible] duced to powder. One of the sides, *k*, is pierced with an eye-hole, which[illegible] occasionally opened to let the slags run out.

The ores usually smelted in these furnaces, are the differe[illegible] oxides of iron, called marsh ore, bog ore, ochres, both yello[illegible] and red, hæmatites, sparry iron ore; none of which require pr[illegible] vious roasting, as not being united with sulphur or arsenic. Th[illegible] ore reduced to small pieces is mixed with charcoal, and the fu[illegible] nace gradually charged with it. As the metal is reduced, it d[illegible] scends into the lower part of the furnace, where it is preserve[illegible] from calcination, by a bed of charcoal dust, *p*. As the botto[illegible] of the furnace gets nearly full of iron, the slags flow out at th[illegible] eye-hole; and when the metal appears at this hole, the mas[illegible] which is of a paste-like consistence, is withdrawn and put u[illegible] der the hammer, and forged at once. Some ores even yiel[illegible] steel in this process.

The metallic cakes, called loupes, weigh from 2 to 4 cwt., an[illegible] three or four of them may be obtained in a day and night. I[illegible] smelting the hæmatitical ores, 7 cwt. of charcoal are consume[illegible]

making one of iron; but only 3 cwt. in smelting the sparry on ore; and a single Catalan forge will furnish 90 cwt. of iron y the week from this ore.

It is, however, more usual to obtain tough iron from cast iron nd finers' metal, by various processes of refining, by means of harcoal.

The tough iron of the Continent is usually obtained from pig on by several successive meltings of the iron in the basin or rucible of a forge hearth, lined with thick plates of cast iron.

To refine pig iron in the German method, called *klump frischen*, the forge hearth is filled with burning charcoal, and the igs of iron being placed opposite the blast, about six or eight nches from the nosle of the pipe, the iron melts, and falls to he bottom of the basin; the workman keeps pushing on the igs, until a sufficient quantity is melted. The slags that are ormed on the surface of the iron, are run off by an opening for hat purpose, and the melted metal stirred with an iron bar, vhich coagulates into a soft mass, which is first turned over to xpose the under surface to the fire, and then brought up oppoite to the blast, and again smelted, and the same treatment reeated until the mass is thoroughly malleable. The mass of ron generally weighs 2 cwt. One hundred parts of gray pig ron loses about 26 in this operation; and each 100 pounds of ough iron, occasions the consumption of 149 pounds of charoal of resinous wood. The operation generally lasts five hours, nd as soon as it is finished the bellows are stopped, the mass is aken from the fire and forged by a hammer of about 9 cwt., to drive out the slags and oxide still remaining in it. The mass is hen divided into four or six pieces, and these are heated and drawn out into bars, on the same forge hearth, while fresh pigs of iron are being melted to form another mass of tough iron.

The German method of *durchbrech frischen*, is similar to he former; but instead of taking out the whole mass of meal to remelt it, only a portion at a time is presented to the blast, in order that the air may have a greater effect in purifying the metal. This method is not so much used as the former.

In the *koch frischen*, *kalt frischen*, or *Rheinische frischen*, as soon as the pig iron is melted, the blast is directed to the bottom of the basin of the forge hearth, the metal is then uncovered and stirred with a rod; it first boils up, and the bellows being stopped, it coagulates into a mass, upon which a little water is flung to cool it. The metal is then taken out of the basin, and again melted before the blast, until it is fit to be forged.

In the *anlauf frischen*, as soon as the metallic mass is re-

melted, a thick rod of cold iron is plunged into it, to which some of the metal adheres; this portion is carried to the hammer and forged. The same manœuvre is repeated with another cold rod, and after thus repeatedly subtracting a portion of the melted iron in this manner, the remainder is treated in a single lump as usual.

The Bergamasque mode of refining pig iron into tough iron is, as soon as it is smelted to run it out upon the floor, which is covered with the finery cinders of former operations, and sprinkle it with water. The plates thus formed of metal and cinder are broken and remelted before the blast, and run into smaller plates, which are again remelted separately in the same fire, and carried to the hammer.

In Styria, the hard pig iron run into plates, is roasted by being heated under a fire of small charcoal for some time to burn out the superfluous carbonaceous matter, after which, the plates are melted upon a forge hearth, the basin of which is lined with moist charcoal in powder. The workman merely stirs the melted metal, and does not raise it up to the blast; so that it appears to refine itself gradually. The mass, when it grows solid, is carried to the hammer, and thus excellent iron is produced.

In the French mode, called *mazéage*, the pig iron is first melted on the forge hearth, and run upon the moist floor of the workshop, to reduce it into thin plates usually of a white and spongy grain. If the grain is gray, the plates are made into conical heaps and roasted. After these preliminary operations, the metal is again melted on the forge hearth, and the mass carried to the hammer.

The Walloon method of refining white cast iron, is merely to melt it under a little slag, and stir it to disengage the carbonic acid gas that is formed: it speedily refines of itself, and fixes into a lump that is capable of being forged.

The Walloon method of refining dark cast iron is to melt it and expose it repeatedly in portions to the blast of the bellows, to burn out the carbonaceous matter, and thus at length obtain tough iron.

As one part of iron is calculated to consume five parts of charcoal in its making, it will follow that two or three parts of potassium may be combined with 100 of iron.

This small quantity of the new metal that can thus be combined with the iron during the different operations that it undergoes, might be supposed to have no effect upon the iron, if we did not know that an equally minute proportion of phosphorus renders iron brittle in the cold, and an equally small quantity of sulphur or copper, renders iron brittle when red hot.

From trials, it was concluded that iron may be united with potassium in two different proportions. In the one, in which the potassium is in the smallest proportion, the iron has a dead white colour, like that of platinum; in the other

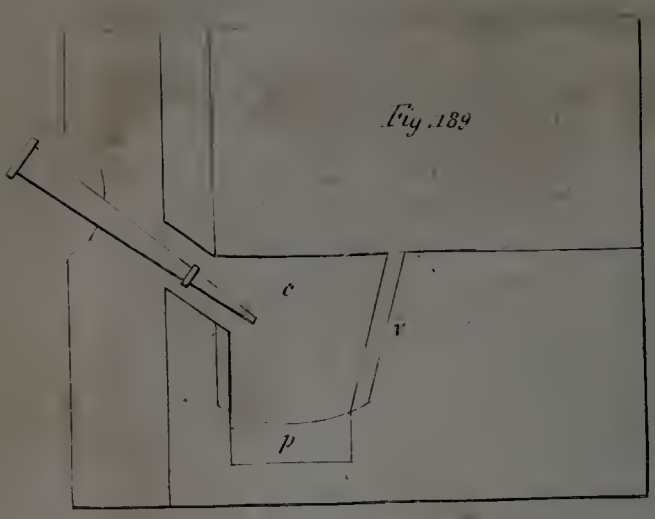



Fig. 189

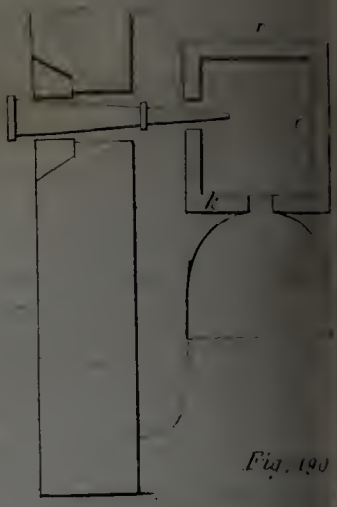



Fig. 190

0 1 2 3 4 Fuß

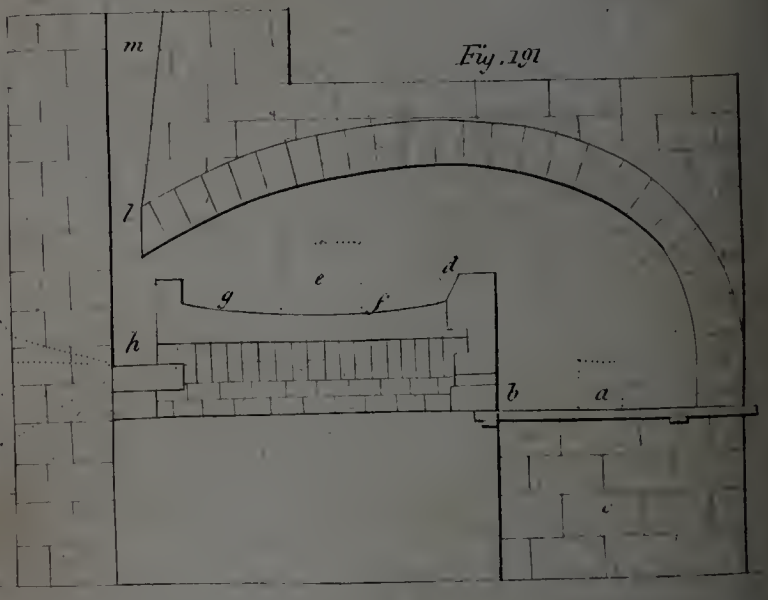



Fig. 191

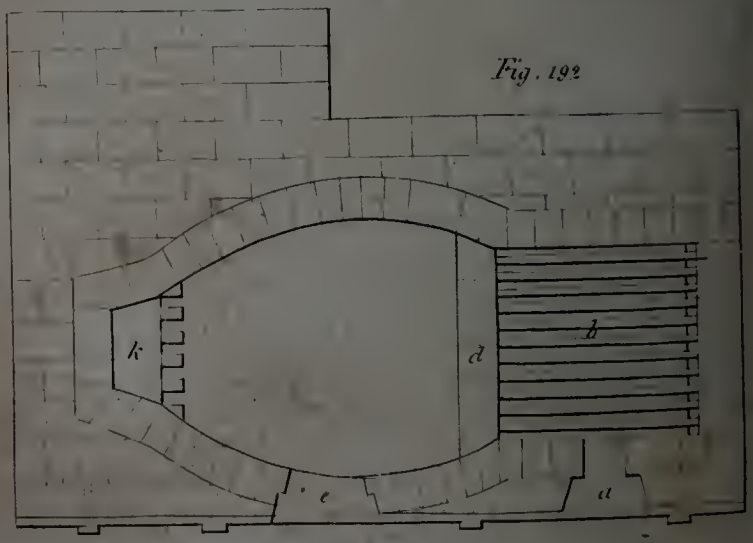



Fig. 192

0 5 Fuß

which the potassium is in the greatest proportion, the iron has a brown colour, mixed with white points.

The white potassinated iron works very easily either hot or cold, is more malleable than iron, and acquires hardness by tempering, but without becoming little like steel. Of course, it is most probable that the small quantities of potassium that combine with the iron, when smelted and forged by charcoal, only help to improve it; and is in fact the cause of the superior quality of the Swedish iron, which is all made with charcoal.

The iron that has combined with the greatest proportion of potassium takes a more or less deep brown colour, mixed with white points. In this state, the parts have but little cohesion; it is cold, short, and probably brittle when red hot.

### *Coke-made tough Iron.*

In the English method of making tough iron, the pig iron is first reduced into finery metal on a finery hearth, called also a refining furnace, or run out furnace. This forge being filled with lighted coke, the pig iron cast in pigs of about half a cwt. each, is placed on the coke, and as it melts it drops through the coke into the basin, where it remains exposed to the action of the blast, for about two hours, or even twice as long, but protected from the contact of the fuel by the slags or cinder on its surface. The basin is then tapped at the lower part, and runs out into the mould. The finery metal has a very white grain, similar to steel.

Fig. 191, represents the plan of the ball furnace, puddling furnace, or reverberatory furnace, used in England to convert finery metal into tough iron, by means of raw stone coal. Fig. 192, is the vertical section, in the direction, *, *. *A*, is the fire door. *B*, is the grate, which is about three feet each way. *C*, is the ash room. *D*, is the bridge between the fire and the basin. *E*, is the opening, by which the furnace is charged. This opening is closed during the process, by means of a cast-iron door, lined with brick work, suspended at the end of a lever, as will be shown in the Hartz cupola for cupelling silver. This door has in the lower part a small opening, by which the workman introduces his tools, and which he afterwards shuts by means of a small door, in which is an opening or spy hole, about ¾ inch in diameter, to inspect the state of the work. *F*, is the bed of the furnace, 4½ feet long, and 4 feet wide, made of very unfusible sand, which is heaped upon a flooring of bricks. *G*, is the edge of the sand bed, with several gutters to allow the slags to run off. *H*, is the basin, into which the slags are allowed to run. *I*, *k*, is the opening by which the slags are run out of the furnace. *L*, *m*, is the chimney, which rises 40 or even 50 feet above the top of the furnace. The whole of the furnace and chimney is firmly bound together by strong bars and cramp irons.

In order to obtain tough iron from the finery metal, the reverberatory, puddling, or ball furnace, is first brought into heat with raw coal, and then there are placed upon the bed 300 pounds of the finery metal, the opening by which the bed was charged is closed with its door, and the little wicket also closed. In about half an hour, the metal is usually melted, and then the workman introduces by the wicket an iron rod, and stirs the melted metal to expose all parts of it to the flame;

during which time the metal swells, and throws out sheaves brilliant sparks. As the iron becomes pure, it fixes in grain which are united together by the workmen, and formed int small balls. The slag or cinder that swims on the metal, run out as often as the basin is full. The metal thus refine is brought together into several small balls, which are place round the bed of the furnace, where they remain exposed the action of the flame until they are taken out one by one, be submitted to the stamping hammer or rollers. The who operation generally lasts an hour and a quarter. As soon the last ball is taken out, the furnace is charged afresh.

The rollers which are mostly used in England for the sal of despatch, instead of the hammer to squeeze out the remai ing slag from the iron, and convert it into bars, are groove with channels of different sizes. In the first pair of roller the grooves are four in number, and the lump of iron from th ball furnace is passed through them in succession. After thi the lumps or blooms are heated in another reverberatory fu nace, with a flat hearth, and passed through another pair rollers, grooved with six channels of different sizes, and a then considered as reduced to saleable iron. Hammered b iron is, however, esteemed of superior quality to rolled iron

In this mode of refining, it requires 4 cwt. of pig or ca iron to obtain 3 cwt. of bar iron, and each pound of bar ir causes the consumption of 6 pounds ·6 of raw coal for its r fining; to which, if there be added the quantity of coal or co required for smelting the pig iron, it will appear that ea pound of coal made iron, has consumed 10 pounds of coal its manufacture.

Coke-made iron, is used for the coarser purposes of the art where great strength in a small bulk of the material is not r quired: its price is generally ¾ that of charcoal-made iron.

### *Soldering for Iron.*

When the filings of soft cast iron are melted in a crucib with borax, which has been previously calcined in order get rid of the water it contains, a hard, shining, black pitc like soldering substance is obtained, being glass of borax c loured black with iron.

Sal ammoniac having been applied to the internal joinin or between the overlapped edges of thin sheet iron, some this black solder being powdered is to be laid along a sho portion of the joint, and as soon as it is melted over a cle forge fire, the soldered part is to be placed on the beak of anvil, and beaten with a light hammer and quick hand, as lo as the heat permits. More of the powder is then to be la

on the adjoining part of the joining, until the whole of the am is soldered.

Another method, which has been published for this purpose, to melt five ounces of borax in an earthern crucible, and hen melted, to add half an ounce of sal ammoniac, and pour e melted matter upon an iron plate. When cold, it will ap- ar like a glass, and is to be powdered and mixed with an ual quantity of unslaked lime.

The iron or steel being heated to a red heat, a little of the ove powder is to be sprinkled on the surface, where it will elt like sealing wax. The iron or steel is then to be again eated, but considerably below the ordinary welding heat, then ought to the anvil, and hammered until the surfaces are per- ctly united.

### *Natural Steel, or German Steel.*

This steel is the most impure, unequal, and variable of the rce kinds of steel, but it is considerably cheaper; it has also he property of being easily welded either to iron or to itself, nd some other qualities which render it frequently preferable the other two kinds of steel.

Its grain is unequally granular, sometimes even fibrous; its olour, usually blue; it is easily forged; it requires a strong heat temper it, and it then acquires only a middling hardness; when rged repeatedly, it does not pass into iron so easily as the other inds.

There are subdivisions of this steel, that are procured from ast iron, and that obtained at once from the ore.

The steel yielded by cast iron, manufactured in the refining ouses, is known by the general name of *furnace steel;* and hat which has only been once treated in the refining furnace, s particularly called *rough steel*, and is frequently very une- ually converted into steel. Both these varieties are drawn into ars, then hardened, and broke into pieces.

Some manufacturers examine these pieces, sort them accord- ng to the appearance of their grain and fibres, and uniting se- eral bars, either of the same or different qualities, into a bun- le, they forge them, and draw the whole out; in this manner hey procure the steel called twice marked. The bars of this teel are sometimes folded together several times, and again drawn out into bars, called thrice marked steel; this steel is ighly elastic, more perfect, and of greater price than the for- ner.

The best cast iron for the purpose of making natural steel, is hat obtained from hæmatites, or from sparry iron ore; if it con-

tains manganese, this is thought to be of advantage. It shoul be of a gray colour; white cast iron does not yield steel, unles its charge of carbon is increased, either by stirring the melte metal with a long pole, and keeping it melted a long time, tha it may absorb charcoal from the lining of the furnace, or b melting it with dark-coloured iron. Black cast iron yields bad brittle steel, unless the excess of carbon that it contains i either burnt away, or is mixed with finery cinder. The cas iron to be converted into steel, is then melted in blast fur naces, and treated nearly the same as if it were to be refine into bar iron, only the blast is weaker, the twyer, instead of be ing directed so as to throw the wind upon the surface of th melted metal, is placed nearly horizontal, the melted metal i kept covered with slag, and is not disturbed by stirring: whe the iron is judged to be sufficiently refined, and is grown solic it is withdrawn from the furnace and forged. After this natu ral steel is made, there is almost always taken out of the re fining furnace, towards the end of the operation, one or mor pigs of iron, which is rather hard, and used for implements c husbandry.

Natural steel is sometimes made at once from the above-me tioned ores in small blast furnaces; which, from their being muc used in Catalonia, in Spain, are called Catalan forges. The ste produced in them is a good steel for ploughs, and similar m chines; that with three marks is excellent for springs and swor cutlery.

That is the best natural steel which is the densest, becom the hardest when tempered, and is not brittle. Its grain shoul be very fine and equal, and it should be capable of being forge and welded without breaking or splitting; lastly, it should sup port the action of the forge well, without changing its nature.

Natural steel has, in general, the defect of being strawy, c containing parts which are not steel, but merely cast iror Sometimes it is cindery, its surface being covered with sma holes; but this seems merely accidental, and owing to its bein treated with too strong a heat. It is in order to remedy thes defects that this steel is bundled together and forged.

The most estecmed natural steel made in Germany, is that c Styria: it is usually sold in chests or barrels, two and a half c three feet long. Its grain is even, close, and fine, but when po lished, it shows fibres, cinders, and threads, from which eve this steel is not entirely free. Sometimes, when broke, it ha in the middle of the fracture a spot, yellow, orange, or blue which is called the rose, and the bars in which it appears ar called *rose steel.* It has been thought, that this rose was a mar of goodness, and the manufacturers of steel in other places hav

tempted to imitate it; but in fact, this rose is a sign of defect, id is only found at the place where the bar breaks with the eatest ease: indeed, it appears to arise from a straw which is rmed at the time of tempering the steel. Files, and the best inds of tools, are usually made of this steel in Germany; the oper colour for hardening it, is a cherry red heat.

The next esteemed steel, is that called distinctively *German eel*, or *Pont stuff*. It is not so good as the former; is sold ther in bars, 10 or 12 feet long, or in barrels about three feet ng; it is marked with an anchor, or seven stars in a circle. his is the most used.

There is also a steel in Germany, called *Cologne steel*, forged bars 3 inches ·5 long, 1 inch ·25 wide, and 0 inch ·75 thick; nother called *Soligen steel, Hungarian steel*, marked with oak leaf, and sold in bundles of four or six bars, fastened to- ether with iron bands: the bars are of different sizes, but one nch ·25 square.

The French have also manufactured natural steel for a long me, but it is only lately that they have begun to improve their uality, and to attempt to rival the German steel. The best rench steel works are those of Rives, in the department of the sere, which is used for large cutlery, and might perhaps be used r the finest. The steel of Berardiere is used for all kinds of prings, as also for cuirasses, which are usually made of iron; ut those of this steel, well forged, offer four times the resist- nce, although equally light, and not dearer. The natural steel f La Hutte, department of the Vosges, is esteemed excellent or saws. Good natural steel is also manufactured at Neron- ille, in the department of the Nievre, and sold in pieces six to even inches, five long, and an inch and a half square, marked vith an N.

Fig. 193, represents the plan of a forge hearth used at Koenigs-huette, to btain natural steel from pig iron. Fig. 194, is a vertical section, in the line, *u*; and fig. 195, another vertical section, in the line, *y, z*. This forge hearth s built under a chimney or hood, as usual. *A*, is a slab of refractory sand-stone, orming the bottom of the basin or hearth. *B*, is a space filled with moistened mall pieces of charcoal, and under which is a layer of rammed clay, *x*. *D*, is plate of cast iron, forming one side of the hearth. *F*, is another plate of cast ron, forming that side that is opposite the blast hole. *G*, is the cast iron plate, f the side towards the blast hole. The basin on the back side, *d*, is only five nches and a half deep, but on the front, and the side, *f*, it is eighteen inches eep; but the back side, *d*, is raised by means of a bank of dry charcoal, to he same height as *f*. *I*, is an opening, by which the slags are run out during he work, and by which the cake of steel is raised up when it is finished. *K*, *m, n*, are lumps of cast iron, that are used to confine the fire on the front vhere the workman stands. *O*, is the floor of the workshop. *P*, is a copper wyer, which is placed at four inches and a half from the bottom, *a*, inclines ve degrees towards it, and is advanced four inches into the fire; the opening eing one inch and a half long, and an inch high. *Q*, are the noses of two ellows, of an inch in diameter each.

Natural, or German steel, does not take a very excellent polish, or take a very hard temper, nor is perfectly alike in every part, some parts being, in fact, only iron beginning to be converted into steel; but it may be forged and welded together very easily.

The steel brought from Bombay, by the name of wootz, or Indian steel, is also a kind of natural steel; for it is obtained by smelting the ore in melting pots, several of which are placed in the same blast furnace. This kind of steel is remarkable for the beautiful veiny appearance instruments made of it exhibit, when polished, as though they were composed of iron and steel welded together, and repeatedly twisted. This veiny appearance has been long known to the sword cutlers, and having been first seen in the sabres made at Damascus, acquired the name of damask, and even communicated it to a kind of woollen cloth, exhibiting the same veins. The damask of wootz, cannot be the effect of the mechanical mixture of iron and steel, since it retains the appearance even after being melted.

M. Breant is of opinion, that Indian or Damascus steel, is a steel more highly charged with carbonaceous matter than the European, and in which, by means of slow cooling, a separation takes place; and two distinct crystallizations, namely, of pure steel, and carbonized steel, takes place. Pure steel does not crystallize, and although when mixed with iron, the damasking or moirée takes place, it is white and very slight. It is only when the carbon is in greater quantity than in steel, so that a part of the mass is in the state of cast iron, that the damask is produced, when the steel is slowly cooled, and then plunged into acidulated water, as this acting upon the steel, and rendering it black, renders its crystallization visible.

Very dark gray cast iron, reduced to grains, melted with an equal weight of the same previously calcined, produced excellent Damascus steel for swords. Damascus steel was also obtained by melting one hundred parts of soft iron, with two of lamp black.

Steel also becomes damasked, by being melted with a very small proportion of silver, chrome, and other metals, as described by M. Faraday.

### *Blistered Steel.*

The cementation of iron, converts it into blister steel.

The furnaces used at Sheffield for making steel are, according to Mr. Collier, conical buildings; about the middle are two troughs of brick or fire-stone, which will hold about four tons of bar iron. At the bottom is a long grate for the fire.

Fig. 194

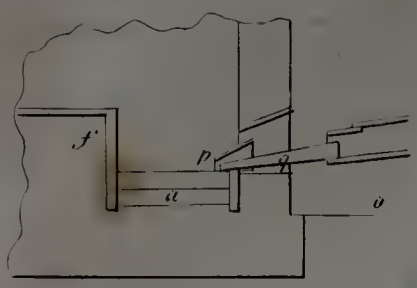



Fig. 193

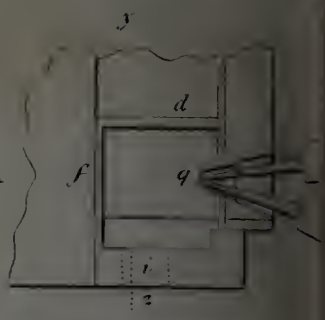
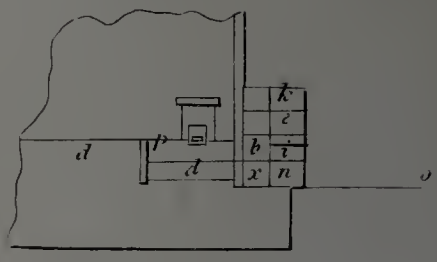



Fig. 195



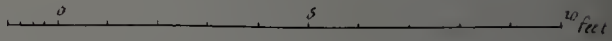




Fig. 197

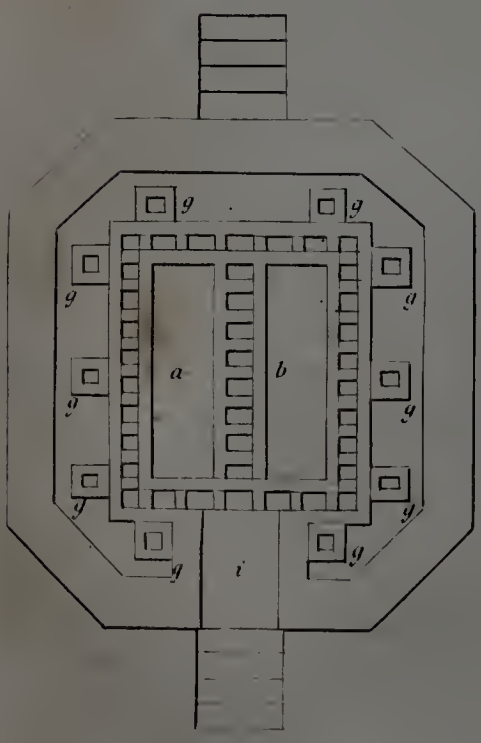
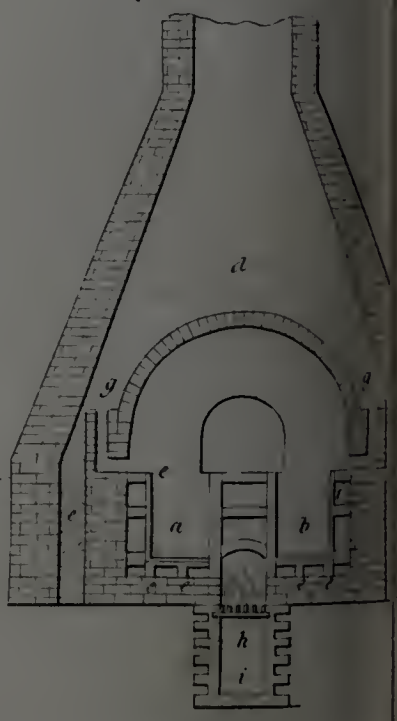



Fig. 196



A vertical section, and horizontal plan of the converting furnace, is shown in gs. 196 and 197.

*C*, is the external cone, built in a substantial manner of stone r brick-work. Its height from the ground should not be less ıan 40 or 50 feet; and to procure a still stronger heat, a cyndric chimney, of several feet in length, is most generally uilt on the top of the cone. The lower part of the cone, hich may be made of any dimensions, is built either square r octangular. The sides are carried up until they meet the one, giving the furnace the appearance of a cone cut to a square r octangular prism at its base, and exhibiting the parabola, here every side intersects the cone.

Inside the conical building is a smaller furnace, called the ault, built of fire brick or stone, which will withstand the ction of the most intense heat. *D*, is the dome of the vault, nd *e*, are its upright sides; the space between which, and the all of the external building, is filled with sand and rubbish. *a*, *b*, represent the two pots that contain the iron to be conerted into steel. The space between them is about one foot n width, and the fire grate is directly beneath it. The pots re supported by a number of detached courses of fire-brick, s shown at *e*, *e*, in fig. 312, which have spaces between them, alled flues, to conduct the flame under the pots. In the same nanner, the sides of the pots are supported from the vertical alls of the vault, and from each other, by a few detached tones, *f*, placed so that they may intercept as little as possible of the heat from the contents of the pots. The adjacent sides of the pot are supported from one another by small pieces of tone work, which are also perforated to give passage to the lame. The bottoms of the pots are about six inches thick; the ides nearest together are about five inches thick; and the ther parts of the pot about three inches.

The vault has ten flues, or short chimneys, *g*, rising from t three on each side, to carry off the smoke into the great cone, shown in fig. 313, communicating with each side, and two at each end. In the front of the furnace, openings are made, which form the door, at which a man enters the vault to put in or take out the iron; but when the furnace is lighted, these doors are closed by fire bricks luted with fire clay. Each pot has also small openings in its end, through which the bars can be drawn without disturbing the process, to examine the process of the conversion from time to time. These are called the tap-holes; they should be placed in the middle of the pots, that a fair and equable judgment may be formed from their result, of the rest of its contents.

*H*, is the fire grate, formed of bars laid over the ash-pit, This ash-pit should have steps down to it, that the attendar to the furnace may get down to examine by the light, whethe the fire upon the whole length of the grate be equally fierce and if any part appear dull, he uses a long iron hook to thru up between the bars, and open a passage for the air. The fir place is open at both ends, and has no doors. The fire grat is laid nearly on a level with the floor of the warehouse, befor the furnace, and the fire door is stopped with a heap of coa piled up before it.

The fire stones composing all those parts of the furnace whic are exposed to the action of the heat, are cemented with we tempered fire clay, mixed up with thin water. The fire cla which answers best for this purpose, is the Stourbridge, i Staffordshire; but very good fire clay for the purpose, is pro cured from Birkin-lane, near Chesterfield.

A layer of charcoal dust is put upon the bottom of the trough upon that a layer of bar iron, and so on alternately, until t trough is full. It is then covered over with clay, to keep o the air; which, if admitted, would effectually prevent the c mentation. The fire is continued until the conversion is com plete, which generally happens in about eight or ten days. T workmen draw out, through the opening in the side, a bar o casionally, to see how far the change has proceeded. This the determine by the blisters upon the surface of the bars. If th change be complete, the fire is extinguished, and the steel left to cool for about eight days more, when the process f making blistered steel is finished.

For small wares, the bars are drawn under the tilt hammer to about half an inch broad, and three-sixteenths of an inc thick.

The best Swedish iron for making blistered steel, is that c Oregrund and Dannemora, and are distinguished by the mark hoop L, PL, double star, and double bullet.

The steel, which in cementation becomes covered with larg blisters, is of a hard quality, and is used for files, razors, an some other implements; and that which is covered only wit small blisters, is mild, and therefore proper for saws, swor blades, springs, and similar articles.

The iron gains by being converted into mild blistered stee four ounces in a cwt., and into hard steel, 12 ounces in a cw If the cementation is continued farther, pig iron is formed.

In some manufactories, the cement is composed of fou pounds each of charcoal dust, of wood soot, and of woo ashes, with three pounds of salt.

Blistered steel takes a better polish, and a harder temper

han natural or German Steel; but it is neither so mueh alike n every part, nor is it so easily forged or welded.

An imitation of German steel is made by breaking the bars f blistered steel into small pieces, and then putting a number f them into a furnace; after which, they are welded together, nd drawn to about eighteen inches long; then doubled, and velded again; and finally drawn to the size and shape required or use. This is also called *shear steel*, and is superior in qua- ity to the eommon tilted steel.

### *Cast Steel.*

Blister steel of the proper quality, either hard or mild, is hanged into cast steel by being broken into small pieces, put nto a black melting pot, and eovered with a mixture of quick ime and powdered green bottle glass, in order to keep the air rom acting on the steel while being melted; but some manu- acturers think it is better merely to eover the pot, whieh is laced in a powerful melting furnace, and kept there for six or even hours. The steel is then cast into ingots.

This steel is perfectly alike throughout its whole substance, nd takes a beautiful polish; but it is extremely difficult to orge or to weld, either with itself, or with iron.

To forge it, the ingot of cast steel must be first heated only o a warm heat, and then slowly hammered until it is rendered compact; after which, it may be hammered quicker. The cast steel must never be heated beyond the least heat necessary to forge it, for the slightest excess will eause it to fly like sand from under the hammer.

Sir. F. Frankland communicated a process, in the Transae- tions of the Royal Society, for welding cast steel and malleable iron together, which he says is done by giving the iron a mal- leable, and the steel a white heat; but, from the experiments which have been made, it appears that it is only soft cast steel, little better than common steel, that will weld to iron. Pure steel will not; for at the heat described by Sir F. Frankland, the best cast steel either melts, or will not bear the hammer.

M. Molard has observed, that when blades of cast steel are properly tempered, and then cemented in iron filings in order to reduce their surface to the state of iron, that they acquire the property of cutting iron itself, without losing their edges.

Steel is tempered by again subjecting it to the action of the fire. The instrument to be tempered, may be supposed to be a razor made of cast steel. First, rub it upon a grit stone until it is bright; then put the back upon the fire, and in a short time the edge will become of a light straw eolour, whilst the back is blue. The straw colour denotes a proper temper, either for

a razor, graver, or pen-knife. Spring knives require a dark brown; scissors, a light brown, or straw colour; forks, or table knives, a blue. The blue colour marks the proper temper for swords, watch springs, or any thing requiring elasticity. The blades for pen-knives are covered over with oil, before they are exposed to the fire to temper.

Fine cutlery is now mostly tempered by immersion in hot oil, whose temperature is ascertained by a thermometer: and some late experiments have shown, that for certain uses, steel is sufficiently tempered long before it is heated, so as to produce any change of colour, even by a heat only equal to that of boiling water.

### *Case-hardened Iron.*

The surface of instruments made of iron, is frequently converted into steel, in order that they may take a good polish and edge.

This case-hardening, as it is called, is effected by heating them in a cinder or charcoal fire; but if the first be used, a quantity of old leather, or bones, must be burnt in the fire, to supply the metal with carbon. The fire must be urged by a pair of bellows, to a sufficient degree of heat; and the whole operation is usually completed in an hour.

The process for case-hardening iron, is in fact the same as for converting iron into steel, but not continued so long, as the surface only of the articles is to be impregnated with carbon.

Some attempts have been made to give cast iron, by case hardening, the texture and ductility of steel, but they have not been very successful. Table-knife, and pen-knife blades have been made of it, and when ground, have had a pretty good appearance, but the edges are not firm, and they soon lose their polish. Common table-knives are frequently made of this metal.

### *Enamelled Iron Vessels.*

It has been generally supposed that of all the metals, iron was the least proper for the purpose of being coated with any kind of glass or enamel. This is, indeed, so far true, that iron does not well bear the common practice of enamellers, namely to be put into the fire and taken out again several times; because the scales which fly from iron, when it is in a hot fire, detach and carry off the enamel.

1. Mr. Rinman reduced into very fine powder, and ground together, nine parts of red lead, six parts of flint glass, two parts of purified pearl-ash, two parts of purified saltpetre, and one part of borax. This mixture was put into a large crucible,

hich it only half filled, and being melted a clear and compact ass was obtained. He then covered an iron vessel, on both les, with this glass, ground with water, and heated it by de- ees, under a muffle, in a furnace. The enamel melted very idily in the space of half a minute, and with a very brilliant pearance, and the vessel was found to be entirely coated with beautiful black colour.

2. He melted together a mixture of twelve parts of flint ass, eighteen parts of red lead, four parts of pearl-ash, four rts of saltpetre, two parts of borax, three parts oxide of tin, epared by calcination with common salt, and one-eighth of a rt of calx of cobalt. A glass of a light blue colour was ob- ined; which, having been ground with water, and spread on small iron basins, or tea-cups, produced by means of a risk fire in a muffle furnace, an enamel which was smooth, ven, and of a pearl colour.

He made many trials with the fore-mentioned ingredients, different proportions, and without the addition of oxide of n; but none of these experiments succeeded better than that st described.

### *Black Varnished Iron.*

Iron is covered with a shining black varnish by merely being heated red hot, d rubbed over with a ram's horn.

### *Tin Plate.*

Charcoal made tough iron of the finest quality, called tin late iron, is used for making tin plate, and being rolled and ut to the usual sizes, from 12 inches $\frac{3}{4}$ to $16\frac{3}{4}$ long, and 9 nches $\frac{1}{2}$ broad to $12\frac{1}{2}$, are first scaled by being bent in the mid- le, steeped for four or five minutes in a mixture of four pounds f muriatic acid, with three gallons of water, and then heated ed hot in a reverberatory furnace, until the heat takes off the cale. The plates are then straightened again, and beaten mooth, when their surface will be found moirée, or mottled, vith blue and white, like marbled paper; after which, they are olled between cold rollers.

The plates are then left for 10 or 12 hours in water, in which bran has been steeped for nine or ten days, and thus turned our; from which they are removed to a leaden cistern, con- aining water soured by oil of vitriol, where they are agitated for about an hour, or until they become perfectly bright and ree from any black spots. After which, they are put into pure water, and scoured in it with tow and sand; and here they are left until wanted for tinning.

The tin used, is a mixture of equal weights of grain ar block tin, which is kept melted in an iron pot, along with son common grease, which is preferred to pure fresh tallow, in t utmost heat that can be used without setting the greas fire.

The plates are first kept for an hour or more in a pot melted grease, and then transferred to the tin pot, where the remain an hour and a half, or even longer, then taken out drained on an iron grating.

The superfluous tin which adheres to the plates, is wa he off, by dipping them into a wash pot, which usually contai three blocks, or about half a ton of grain tin, in a melted stat divided into two parts, by a partition which does not go dow to the bottom. The plate being dipped, is raised up, and on of its sides brushed; it is then turned, and its other side brushe and immediately dipped a third time in the other part of th pot. As the tin washed off the plates, deteriorates the qualit of the grain tin in the wash-pot, as soon as about 15,000 plat have been washed, that is to say, every second or third da about three ewt. of the tin is ladled out, and its place supplie with a fresh block of grain tin.

From the wash-pot, the plates are removed to a pot of me ed tallow or lard, the temperature of which must be varied a cording to the thickness of the plates. Here they are place upright and kept separate, by means of pins in the sides of th pot, which holds five of the plates. Those which have bee in this pot the longest, are removed regularly to an iron gratin to drain and cool.

Finally, the wire, or list of tin that remains at the botto of each plate when cold, is removed by dipping this lowe edge into a pot of melted tin; and after it is taken out, i is struck a smart blow with a thin stick, which disengage this list. The plates are then cleansed from the tallow b means of bran, and packed for sale.

Iron work, of various kinds, as forks spoons, bits for br dles, dog-chains, and the like, are tinned by being scoured wit sand, and put for some time into a pot of melted grain tin, co vered with sal ammoniac.

### *Moireé, or Crystallized Tin Plate.*

This beautiful article is made by taking tin plate, which ha not been rendered too close in its texture by hammering o rolling, warming it, and then washing the surface with we citric acid; or a mixture of two pounds of nitric acid, three o muriatic acid, and a gallon of water. The figures produced vary according to the heat given to the plate; and a still more

autiful effect is produced by heating particular parts of the ate by a blow-pipe.

The tin plate, when its surface has been thus crystallized, is rnished, either with clear, or coloured varnish.

### *Bronsed Iron.*

The practice of coppering takes place in iron only. It may done in the first place, by immersing the pieces of iron, if nall, in a solution of vitriol of copper; but if they are large, ey must be frequently brushed over with it. Secondly, it ay be performed with copper-powder, which is laid upon a in covering of varnish, and polished.

### *Browned Iron.*

The barrels of fire arms are browned in the following man-r:—

Nitric acid half an ounce, sweet spirit of nitre half an ounce, irit of wine one ounce, blue vitriol two ounces, tincture of el one ounce. These ingredients are to be mixed, the vitriol ving been previously dissolved in a sufficient quantity of ater, to make with other ingredients one quart of mixture. he mixture is to be applied with a clean sponge or rag; the rrel must then be exposed to a slight heat, after which, the rrel must be rubbed with a hard brush, to remove the oxide om the surface.

This operation may be performed a second and a third time, requisite, by which the barrel will be made of a perfectly own colour. It must then be carefully brushed and wiped, d immersed in boiling water, in which a small quantity of otash has been put. The barrel, when taken from the water, ust, after being rendered perfectly dry, be rubbed smooth ith a burnisher of hard wood, and then heated to about the mperature of boiling water; it will then be ready to receive varnish made of the following materials:—Spirit of wine vo pints, dragon's blood pulverized three drams, shell-lac ruised one ounce; and after the varnish is perfectly dry upon ie barrel, it must be rubbed with the burnisher, to give it a nooth and glossy appearance.

Iron is sometimes browned in a simpler manner. It is mere-rubbed over with water soured by aqua fortis, or by spirit f salt, and is then laid by until a complete coat of rust is rmed. The iron is then rubbed with a little oil, and polished y means of a hard brush, and some bees' wax.

## *Copperas.*

The English copperas, or green vitriol as it is also called, is made from the natural combination of iron with brimstone, called iron pyrites, or in common language, copperas stones, gold stones, or horse gold, from their colour.

These stones being collected in great quantity, are laid in heaps about two feet thick, upon a clay floor, surrounded by boards that direct the rain water that falls upon them, to flow into a cistern. The clay floors at some works, are 100 feet long, 15 feet broad at top, but narrowing to 12 feet at bottom, as they shelve gradually to allow the rain water to run off easier. The cistern usually contains about 100 tuns of water.

The copperas stones are five or six years before they yield any considerable quantity of strong liquor; the liquor being before that very weak. The sun and rain are the proper agents; for it has been found that other water, although prepared by lying exposed to the sun, and sprinkled on the stones only retards the work. In time these stones turn to a vitrioli earth, which swells and ferments like leavened dough.

When a bed is come to perfection, it is refreshed every fou years, by laying fresh copperas stones on the top. When new bed is made, the work is hastened by mixing a goo quantity of the old fermented earth with the new stones.

When the copperas liquor is 14 pennyweights strong, that i weighs fourteen-eightieths more than an equal measure of w ter, it is esteemed rich; but in rainy seasons it is much weake The sulphuric acid is not saturated, as it will dissolve the she of an egg in three minutes, and produce holes in any clothe on which it may fall or spatter.

The copperas liquor is boiled in leaden vessels, containin about 12 tuns; about a cwt. of old iron is put in at first, an more added as fast as it dissolves; amounting in all to near 15 cwt. in a boiling. As the water evaporates, fresh is adde from a second boiler, heated by the same fire.

The boiling is esteemed finished, when a little of the liquor put into an earthenware dish, and cooled, deposites crystals o the sides. The liquor is then run off into a tarras cistern, 2 feet long, 5 feet deep, 9 feet over at top, but tapered toward the bottom, where it is left for a fortnight to cool, and the drawn off, and reserved to be boiled with new liquor. There is generally a crystalline mass, five inches thick, left on th sides and bottom of the cooler, the copperas adhering to th sides is of a bright green, that at bottom foul and dirty. It shovelled out upon a floor, and the liquor that drains from it reserved along with the other.

If the furnace is well constructed, the copperas liquor moderately rich, and the water, that is added to supply the waste, nearly boiling hot, three boilings may be made in a week.

In some works, iron is added to the liquor in the cistern; and of course less is required in the boiling.

There is another kind of pyrites, which contains a double proportion of sulphur; this sort does not alter by exposure to the weather, until the extra proportion of sulphur is removed either by roasting in piles, or by distilling in close vessels.

There is also a kind of bituminous earth that produces copperas by exposure to the air, and from which it may be obtained by washing with water in the usual manner.

Copperas is also manufactured by dissolving old iron in weak sulphuric acid, at 35 deg. Baumé, and crystallizing the solution.

Immense quantities of copperas are used for dying black colours, in the manufacture of common ink, and for many other purposes.

Copperas is the *sulphas ferrosus* cum aquâ, of the Northern Chemists, or Fe: S:· 2 + 14 H 2 O, and its weight 3,454,840; it is the *proto sulphate of iron* of Dr. T. Thomson, or Fe· S:· + 7 H·, equal to 17,575.

Copperas water is used to discover the presence of oxygen gas in a mineral water.*

### *Colcothar.*

This red oxide of iron is obtained generally from the residuum of the distillation of saltpetre with copperas, for making aqua fortis, by washing it.

It is used for polishing iron or steel, and is sometimes called *trip* or *brown red.*

A superior kind is obtained by calcining copperas by itself, in a strong heat, in an earthen dish. The scarlet parts are called *rouge*, the red, purple, or bluish parts, being those which have been exposed to the strongest heat, are called *crocus.*

*Jewellers' rouge* is made by dissolving copperas in water, filtering the solution, and adding a filtered solution of pearl-ash, or of subcarbonate of soda, as long as any sediment falls. The liquor is then filtered again, and the sediment left on the filter, washed by running clean water through it, and then calcined until it is of a scarlet colour.

## SILVER.

Silver does not admit of any varieties of denomination, like the preceding metals. Being very valuable, it is always re-

* For an account of the method of preparing the pyrolignate, or acetate of iron, (iron liquor,) co-extensively used in calico printing, see the article "calico printing," in this work.—Am. Ed.

fined at the mines to a nearly uniform purity; and nothing but a small quantity of copper, and sometimes of gold, is left in it.

The purity or fineness of silver, is estimated in England by reference to what is called standard silver, which is an alloy of 11 ounces of pure silver, and one ounce of some other metal, generally copper, to the Troy pound; and is expressed by stating how many pennyweights and half pennyweights of pure silver, there is contained in a Troy pound of the mass, more or less, than in standard silver. In the first case it is said to be 1, 1½, 2, &c. dwts. better; and in the latter case to be 1, 1½, 2, &c. dwts. worse than standard.

Silver melted in an open vessel, absorbs oxygen from the air; but when it fixes, this oxygen, like the air from water in freezing, quits it; and this so suddenly, that the silver rises in vegetations, and is sometimes spurted out of the vessel.

The quantity of silver annually extracted from the mines of Europe and America, is about 850 tons.

### *Assaying of Silver Ores.*

The value of silver, and the small quantity in which it i often found in its ores, require these ores to be assayed with great care. The ores of silver are, for this purpose, divide into three kinds.—1. *Ores of easy fusion*, under which are comprised native silver; the vitreous and corneous silver ores the red and white silver ores; and some others.—2. *Was ores*, which are mixed with stony matter, and must be separated from it by washing.—3. *Refractory ores*, which are either mixed with refractory materials, or with other kinds of ores as cobalt, pyrites, or copper, in such a manner that they can not be separated from them by washing.

With respect to the silver ores of easy fusion, there are three operations chiefly to be attended to: roasting, scorification with lead, and cupellation. As to the roasting, there are, it is true some silver ores that may be assayed without roasting, which are suffered to roast during the scorification by lead. It is however, safer previously to roast the ore a little, particularly if it should contain a small quantity of sulphur or arsenic.

The scorification with lead, is performed in the following manner. One assay cwt. of ore is to be taken either before or after roasting, and eight cwt. of granulated lead added to it First, one half of the lead is to be put into the clay test, or capsule; and upon this the ore, which is afterwards to be covered with the remainder of the lead. Immediately upon this, the capsule is to be put into a well-heated assaying furnace; at first at the mouth of the muffle only, but at length quite into it

nd a red-hot coal is placed before the mouth of the fur ace.

When the lead begins to melt, and the ore swims upon its urface, the mouth of the furnace is to be opened, the coal re- noved and the capsule drawn more forward, that the sulphur nd arsenic may be better dissipated and expelled from the ore, After this, the test or capsule is again put into the furnace, a ed-hot coal once more placed before the mouth of the latter, vhich is then shut up till the lead is seen quite bright and hining in the middle of the capsule, and the ore flowing round t at the sides.

As soon as this is perceived, the furnace is to be opened, nd the capsule drawn forward again, that it may stand for bout the space of a quarter of an hour in a moderate heat o fine. Afterwards, the heat is again increased as before, hat the whole may enter into a smooth and thin fusion, and he whole matter stirred with a hook thoroughly heated, es- pecially towards the sides of the capsule, so that the whole may e equally mixed with the matter in fusion.

When it is observed that the matter adhering to the hook uns off quite thin; that only a thin glassy pellicle is attached o the hook; that the slags towards the sides of the capsule are liquid and clear like oil; that the thick smoke has subsided; that a clear leaden vapour begins to appear; and that, to appear- ance, no more than about half the lead that was added remains in the capsule; the fire for the assay is then to be raised. In the mean time, a small hemispherical ingot-mould is to be rubbed over with chalk; the capsule is to be taken out of the fire, and the work, as it is called, immediately poured into the ingot mould.

Upon this the cupellation must commence. During the sco- rification of the ore with lead, two cupels must be inverted quite in the back part of the furnace, that their bottoms may become thoroughly red-hot: this is called breathing the cupels. When the scorification with lead is finished, the cupels being set upright in the furnace, are to be left there in the proper de- gree of heat, and the mouth of the furnace is to be closed again. The whole of the glass and scoriæ is then to be separated from the work which is to be hammered round. At the same time, a quantity of granulated lead is weighed out, equal to that which has been used in the scorification, which lead is called the weigh-lead.

The work is to be put into one cupel, and the weigh-lead into the other, and the same degree of heat is given to both, till the assay begins to look bright and clear; the assay is then to be conducted a little more gently, but not so that it shall

*fix*, of which the following are the most certain signs:—The appearance of a brown ring round the inside of the cupels; the vapour of the lead rising only a little above the brim of the cupel; a bright circle, like oil, is at times perceived encompassing the work; the appearance of several shining rays, at different intervals, round about the work. This degree of heat must be continued till the quantity is diminished to about half; after this, the fire must be gradually increased, till the button lightens. When this has taken place, the cupel is left in the furnace till the button is fixed, that it may not be divided into a number of small buttons, by being taken out too soon.

As soon as the assay is become solid in the furnace, it is taken out, and the button immediately detached from the cupel by a stroke with the point of the cupel tongs, before it adheres too fast. The same method is to be pursued with what remains of the weigh-lead in the other cupel. After this, the amount of the latter must be subtracted from that of the former, and the remainder only set down as the contents of the assayed quintal.

The above-mentioned cupellation of the mere weigh-lead must be undertaken at the same time; on account that nearly all lead contains a small quantity of silver. By this means the amount of the silver it contains is ascertained, and subtracted from the actual product of the assay of the ore, to which it necessarily must have adhered from the lead that was added.

*Wash ores*, which are interspersed in stones and matrices of ores, must be previously freed from them as much as possible, then stamped tolerably fine, washed, and roasted. An account having been taken of the loss sustained by the ore in the washing and roasting, an assay cwt. of the roasted ore is to be weighed out, a cwt. of glass of lead, made by melting litharge with half its weigh of calcined flint, and twelve of granulated lead are to be added to it. The processes of scorification, and cupellation ore, are then conducted as usual.

*Refractory silver ores*, which cannot be washed, must first be exposed for some time to a red heat, and roasted. After this, they are to be mixed with the very same ingredients and those in the same proportion as has been mentioned of the wash ores. They require a brisker fire in the fusion and scorification of them by lead. The work thus obtained, is then to be cupelled.

For assaying various kinds of earths and stones for silver, one assay cwt. of these is to be mixed with the same quantity of glass of lead, then scorified and cupelled with 12 cwt. of lead. Or these three ingredients are to be mixed together in

qual parts, covered with common salt, and brought to perfect sion; or one part of these stony substances may be fused to ass in a crucible, with two parts of litharge or minimm, in a rge fire, which glass is afterwards to be powdered, mixed ith twice its quantity of black flux, then fused afresh, and e regulus of lead thus obtained submitted to the cupel.

It often happens that melted metals contain a portion of sil-er, and must be assayed to know what proportion they con-in.

With this view, regulus of antimony is scorified in a test or apsule, in a very gentle heat, with eight or ten times its quan-ty of lead, till the colour of the fumes is altered, which in his case is usually brown, and the gray fumes of lead appear, vhen it is suffered to stand half a quarter of an hour longer. The lead is then separated from the scoriæ, cupelled, and the ilver button weighed.

Zinc is calcined by itself in a crucible, and an assay cwt. of scorified and cupelled with two cwt. of glass of lead, and welve of lead.

Bismuth is mixed with from four to six times its quantity of ead; and in every respect treated like regulus of antimony; he fumes arising in the scorification of it by lead, are only in-lining to brown.

To assay iron for silver, to half an assay cwt. of iron, one cwt. of sulphur is to be added, and put into a capsule rubbed over on the inside with chalk, which after being covered with another, must be placed quite in the fore part of the assay-fur-nace, and roasted with a gentle heat. When the sulphur is ex-pelled from it, the residuum is weighed out, with eight times its weight of lead, for the assay, scorified in the capsule, and then submitted to cupellation.

The assay of lead for silver is easily conceived. If the lead contains an ounce of silver in the ton, it is considered worth separating.

To assay tin, half an assay cwt. of it is to be added to two cwt. of lead. This is to be set forward in the mouth of the furnace, so that it may become a little red: after a short time, the tin covers the surface of the lead in the form of a gray calx. This gray oxide is to be taken off by little and little with an iron ladle, and pushed towards the sides of the cap-sule till the whole is calcined. All the oxide of tin collected together is to be mixed with an equal or twice the quantity of glass of lead, and again put into the furnace in a capsule. Af-ter which, a quantity of lead is to be added to it, equal to ten times the weight of the oxide of tin, and the whole to be sco-rified and cupelled, like a refractory silver ore.

To assay copper, half an assay cwt. of it is to be cupelle with 16 cwt. of granulated lead.

The various sorts of silver plate and coin, which differ with regard to fineness, are to be assayed in the following manner The silver is first to be rubbed upon the touchstone, and th marks compared with those of a known alloy, in order to ob tain an approximation towards the proportion of copper con tained in it, so that the quantity of lead to be added may b determined afterwards.

This is done in the following manner.

Silver 20 dwt. better than standard, or fine silver, require three or four times its weight of lead; 10 dwt. better, five o six times; 10 dwt. worse eight or nine times; 25 to 40 dwt worse, twelve or thirteen times; 2 oz. 15 dwt. to 3 oz.; 1 dwt. worse, thirteen or fourteen times; 4 oz. 5 dwt. to 5 oz worse, fourteen or fifteen times; 8 oz. to 9 oz. 10 dwt. sixtee times; and 9 oz. 10 dwt. to 10 oz. 5 dwt. worse than standard twenty times its weight of lead.

The cupels being made hot, the lead in the first place is p into them, and when this begins to circulate the silver is the added. With respect to the fire, the operator must be regulate by the fineness of the silver; for the finer the assay is, th brisker the fire must be; and the more copper there is containe in the assay, the lower the fire is to be kept. But all assay agree in this, that they all ought to lighten hot, and especiall fine silver, because it is very apt to fix before it is cleared o the other metals. In other respects, the process is the sam as in common cupellations; and the small portion of silver con tained in the lead, must by no means be omitted in the calcula tion.

### *Extraction of Silver from its Ores.*

The Spanish mode of procuring silver from its ore, an which is used in their American mines, is to grind the ore an mix it up with water into a paste. When this is half dry, is mixed with salt and roasted. Afterwards quicksilver is add ed, heated along with the ore, the whole ground together, an at last washed in a stream of water, to carry off the saline an earthy particles.

When the water goes clear, the amalgam is squeezed in bag to get rid of the superfluous quicksilver, moulded in woode moulds perforated at bottom like a colander; and the mass thus produced laid upon a copper-plate full of holes over a trev under which is a large vessel of water. The whole is then co vered with a bell of earthenware, which is surrounded wit

e, by which the quicksilver is distilled into the water, and e silver left upon the copper plate.

Some ores are roasted before the salt is added.

Silver is also obtained at Halsbruecke, near Freyberg, in xony, by means of quicksilver, in an amalgamation work, e whole arrangement of which is regarded as a perfect spe- men of architectural distribution, in regard to the ease and gularity with which the several successive products are moved to the places where they are to be farther acted on.

The ores used in this work, are partly ores in which native lver is disseminated in a matrix without pyrites, and partly f pyritous ores containing silver. The first are stamped and ashed before they are delivered in, and the others are only ressed and washed in bucket sieves.

The ores are assayed, and mixed so that the mixed ore may ntain 3 ounces $\frac{1}{2}$ or 4 ounces of silver in a cwt.; but as in is proportion there is only an ounce or 1 ounce $\frac{1}{4}$ of native lver, which is the only part that can be acted upon by the uicksilver, the mixture is so managed that each cwt. of ore at e same time that it contains 3 ounces $\frac{1}{2}$ or four ounces of sil- er, may also contain 37 pounds of sulphuretted metal, or about 0 of sulphur.

To the mixed ores, there are added one-tenth its weight f common salt, and they are then roasted in a reverberatory urnace; the roasted mass, which of course contains sulphate f soda and muriate of silver, mixed with the native silver, is screened to separate those parts that have run together, and hese being broken small, and again mixed with one-fiftieth or ne-thirtieth their weight of salt, are roasted afresh.

The roasted ore that passes the first screen is again screened and divided into three finenesses; the two finest parcels are ground into a fine powder, the coarsest is mixed with the ore that has run together, treated in the same manner; and thus the whole of the ore is at last reduced to a uniform powder.

Ten cwt. of the ground ore are then put into each of the amalgamation barrels; 3 cwt. of pure water being previously put in each.

Fig. 197, represents two of the twenty barrels, placed in four rows, which are moved by the same water-wheel; the barrels are 3 feet $\frac{1}{2}$ long, and the same in diameter, strongly hooped with iron, and having an iron stirrup, *a*, with a screw, *b*, to fasten down the wooden bung. Gutters are laid under these barrels, to convey away the liquid matters.

The barrels thus charged having been turned for two hours

to mix the ore and water, there are added to each 5 cwt. quicksilver, and 70 pounds of iron forged in circular plates.

The barrels make 18 or 20 turns in a minute, and are turne for 18 hours, when they are thrown successively out of gee and the bung hole being opened, a wooden pipe is inserted i it, with a short length of leather hose, closed at the end by screw cock. The barrel thus fitted, is turned half round by th hand, and the hose being placed in the gutter, the cock opened, and the quicksilver run into a filter of ticken, throug which the liquid quicksilver runs into a cistern, to be used ov again; and the amalgam remains on the filter.

The barrel being again turned, with its bung-hole uppermos is filled with water, and stopped, then thrown into geer to mi the whole, and afterwards emptied in a similar manner, of i contents, into gutters that convey them to the washing-house

The amalgam that remains on the ticken filters, is compose of six parts of quicksilver and one of silver, and is distilled t separate the two metals.

Fig. 198, represents partly the elevation, and partly the section of the app ratus used for distilling the amalgam; while fig. 199, exhibits the plan. *A*, a wooden drawer, which can be drawn out by means of rollers. *B*, is a c iron basin, placed in this drawer to receive the quicksilver. *C*, is an iron p lar, with four legs, standing in the cast-iron basin. *D*, are five plates of forg iron, with a hole in their middle to slip over the iron pillar, and are support by it at some little distance from each other, by the upper half of the pillar, the manner of a dumb waiter. *E*, are cast-iron bells, about four feet hig hooped and bound with forged iron and furnished at top with a ring, to rece occasionally the hook of a crane, by which they may be lifted in and out of t furnace. *F*, is the crane. *G*, is an iron door, lined with clay, which is plac against the opening in the front, when the bell is fitted in its place. *H*, are t openings in front of the furnace, by which the pillar and dishes are put in, a taken out of the furnace. *I*, are the openings by which the fuel is supplied wi air. *K*, is a projection and recess of the masonry, between every two furnace of which there are four serving as a table, on which the dishes are filled emptied. *L*, is a gutter behind the furnace, by which a stream of water conveyed into the drawers. *M*, is a cast-iron plate, resting partly on the be and partly on a ledge in the masonry, and serving as a bottom to the f room.

The drawer of each furnace being thrust in, and the cast-iro dish and pillar placed in it, 3 cwt. of amalgam are placed the dishes, which are then fixed on the pillar; the bell l down so as to rest on the legs of the pillar, the iron plate th forms the bottom of the fire room placed, the front door applic and fastened, and the water let on to fill the drawer, thus e tirely covering the basin and bottom of the bell; a fire is lighte in the fire room, which is brought on gradually—at first turf used, and afterwards charcoal. The distillation usually las eight hours, and is ended when the drops of quicksilver are r

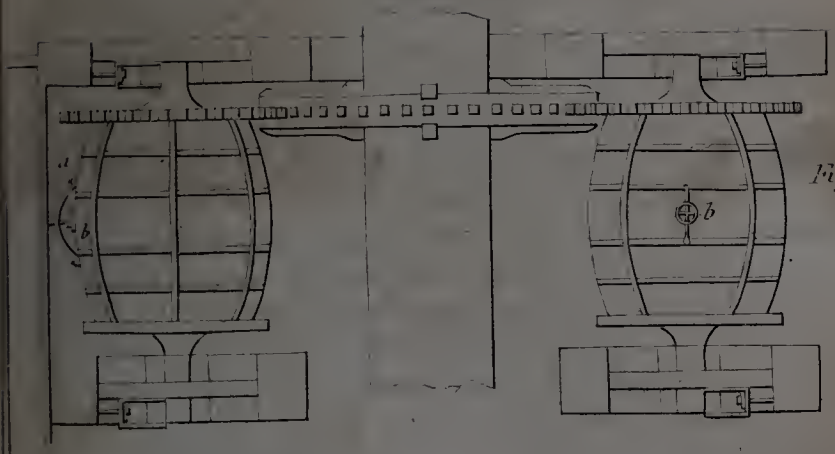
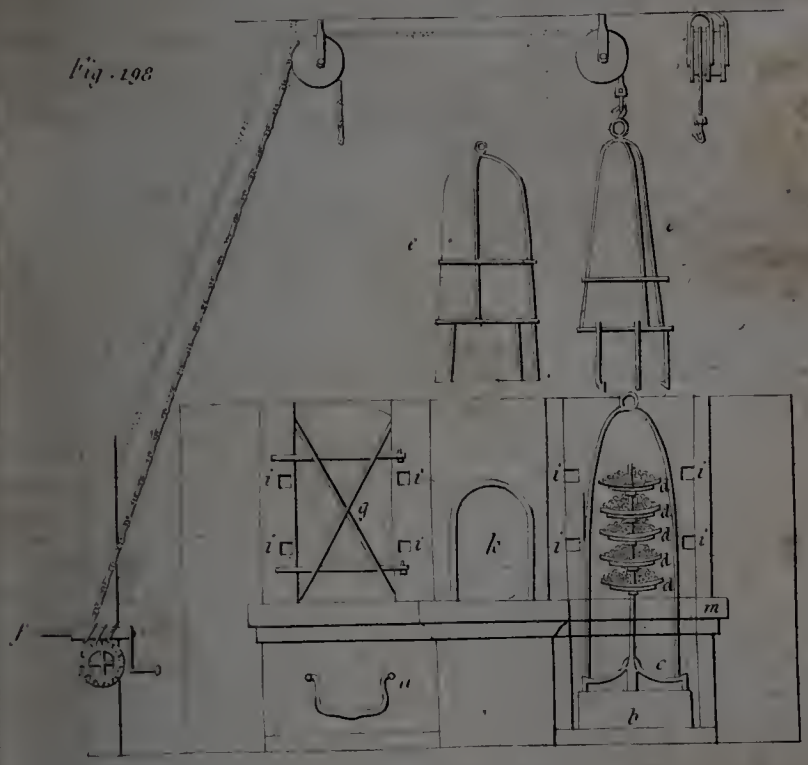



Fig. 197

Fig. 198



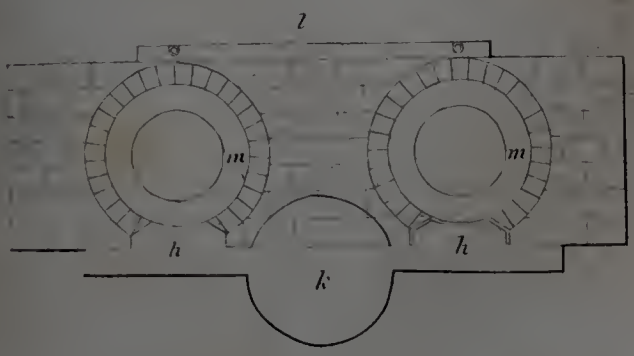




Fig. 199

onger heard falling into the iron basin. During the whole time, stream of cold water is kept running into the drawer, and escaping by its upper edge.

The bell being cold, it is raised up, the silver left on the lishes removed and melted into cakes of 20 or 25 pounds each, eady for cupellation, and the quicksilver collected in the basin, lried by a sponge, and returned for a fresh amalgamation. The ilver usually contains three-sixteenths to five-sixteenths of alloy, being either copper, cobalt, nickel, or such other metals as were contained in the ore; there is usually 550 or 600 pounds obtained every fortnight. The quicksilver retains some silver, but this is of no importance, as it is used over and over again; and there are two parts in 100 of the quantity of quicksilver used, lost in each process.

The residue from which the amalgam was run, and which was washed out of the barrels, is received in large vats, six feet in diameter at top, and the same in depth, having eight plugs at different heights. In each vat an upright spindle is worked, having several iron arms, by which the matter is stirred. The washing is continued for 12 hours, and then the residue is drawn off into waste pits by opening the upper plugs; for those near the bottom are not opened above once in three weeks, when the quicksilver that remained in the mass is collected. After the earthy matters in the pits have subsided, the water is pumped off, and evaporated, by which means a quantity of Glauber's salt is obtained.

The quantity of ore annually operated upon, is about 60,000 cwt., and there is obtained from 140 to 145 cwt. of silver. The substances consumed are, about 25 cwt. of quicksilver, 6000 cwt. of salt, 60 to 80 cwt. of iron, and 345,000 cubic feet of charcoal. The expense is nearly the same as in smelting, the only advantage being the lessening of the consumption of charcoal, and thus keeping down its cost to the works, in which it must necessarily be employed.

The ores worked in Europe for silver, are not properly ores of silver, but lead and copper ores, which hold a small portion of silver. Hence these ores are first smelted for their lead or copper, and then these metals are worked to extract what silver or gold they contain.

For the purpose of separating silver from lead in a large scale of manufacture, recourse is had to cupellation.

The Hartz furnaces, used for cupellation, have a moveable cupola, which facilitates the making of the bed on which the lead is kept in bath.

Fig. 200 represents the elevation of this furnace, taken opposite to the fire room door. Fig. 201, is the elevation of the side of the furnace, taken oppo-

site to the charging door. Fig. 202, is the plan at the level of the blast holes Fig. 203, is the vertical section in the line * * of fig. 202.

In these figures, *A*, is the masonry of the foundation, *B*, are channels for carrying off the moisture. *C*, are stones for covering these channels. *D*, is a bed of slag. *E*, are the bricks which form the bottom of the bed. *F*, is the bed, 9 feet in diameter, which is made, when wanted, of wood ash, generally obtained from the soap boilers, well washed and pressed together. *H*, is the cupola, made of sheet iron, slung to a crane; this cupola is lined on the inside, about two inches thick with clay. *I*, are the blast holes, by which the wind from two bellows is blown upon the bed; the bellows have loose nozles, so that the direction of the blast may be altered at pleasure. *K*, are the bellows. *L*, is the door by which the bed is charged with the lead to be cupelled. *M* is the fire room door; *N*, is a small opening, by which the scum of the bath, and the litharge is let to run out of the bed. *O*, is a basin made for security in case of accidents: this basin is generally covered with a stone, over which the litharge runs; but sometimes the stone is removed, and the lead is run off the bed into this basin.

The bed of the furnace takes about 35 cubic feet of wood ashes, and two hours and a half to make it; at the same time the cupola is lined with clay. The bed is then charged with 84 cwt. of lead, half of which is placed opposite the blast holes and half near the bridge between the fire room and the bed; to this latter is added any thick slags holding lead and silver, so that they may be brought into use. The cupola is then moved over the bed and luted to the furnace, which is first heated very gently with fagots, and as it dries the fire is increased.

In about three hours the lead is melted, it is then watched and as soon as there is no longer any boiling observed on the surface of the bath, the bellows are set in motion, and blown about four or five times in a minute. At the end of five hours the fire is increased, and the first gray scum is drawn off through the small opening; the running off of this scum continues for about an hour and a half, and charcoal powder is thrown upon it to coagulate it, as it is drawn to the opening by a hook.

The litharge then begins to run, and the workman makes a gutter in the edge of the bed, to facilitate its running. During this time the blast is so directed as to produce circular waves on the bath, so as to drive the litharge as it forms to the circumference, and particularly to the opening by which it runs off.

When the litharge has run for about 12 hours, and it begins to form only on the edges of the bath, the litharge that forms afterwards is kept apart, as it contains silver. About this time the heat is augmented, and a brick is placed before the opening by which the litharge runs out; the use of this brick is to keep a reserve of melted litharge at hand in case that surrounding the bath should be suddenly absorbed by the bed, also to keep in the water that is afterwards introduced, and finally to keep in the silver, in case of any detonation or other accident hap-

ening, until the stone over the basin is removed. The litharge hat collects behind this brick is jerked out of the opening by n iron hook.

When the operation has lasted about 20 hours, the silver, ow nearly left pure, appears to form a nearly circular cake: nd at length its surface brightens instantaneously, immediate- y on which a wooden trough is introduced, and water, warmed y throwing red hot iron into it, is poured on the silver.

Some workmen use only 300 billets of wood, each one cubic oot ·8, in this operation; others, less skilful, use 400 billets, r even more: on an average, 100 cwt. of lead consumes 790 ubic feet of billet wood in cupellation.

The products obtained from 84 cwt. of lead, are generally 24 to 30 marks, or half pounds, of silver, retaining seven marks, ne ounce and a half of alloy in each 100 marks; 50 to 60 cwt. f pure litharge; two to six cwt. of the second litharge, re- aining a little silver; four to eight cwt. of the first scum; and 22 to 30 cwt. of the upper surface of the bed, which is impreg- nated with litharge.

The loss of lead is calculated at three or four pounds in very 100; but lately the hoods under which the cupelling urnaces are built communicate with chambers, in which the ead smoke that formerly flew away, is condensed.

Trials have been lately made in the Hartz to improve this process. In the furnace cupelling 100 cwt. of work lead at nce, there was a saving of one quarter of the fuel and wood shes, the produce of litharge was increased four pounds in every 100, while the silver was as usual.

In a furnace cupelling 200 cwt. of work lead at once, there was a saving of fuel and wood ashes, but the quantity of li- tharge and silver was very variable.

In a furnace built at Altenau, to cupell 500 cwt. of work lead on a single bed at once, by means of two fire rooms and four openings for the running off the litharge, the silver did not form a single cake, but part remained on the edges of the bed, nor could the sudden brightening of the silver be produced properly.

In another double furnace with two fire rooms, and their beds placed side by side, and holding 250 cwt. of work lead each, the brightening indeed took place, there was a saving in fuel and wood ashes, and sometimes a large produce of li- tharge, but the quantity of silver obtained was not satisfactory.

From these experiments the Hartz smelters have concluded that it is not profitable to cupell more than 100 or 110 cwt. of work lead at once: and several still prefer the old furnaces that cupell only 72 cwt.

In the Hartz works the operation of eliquation, or sweating cakes of copper that hold a small quantity of silver, is begun by smelting through a blast furnace, and moulding into cakes about 30 separate charges each, containing 90 to 96 pounds of black copper, containing at least two ounces and a half or three ounces of silver in the cwt. along with two cwt. of lead reduced from litharge, and a half cwt. of litharge. The smelting is begun by a charge of slags, then the litharge is added, and when the lead begins to flow out, the copper is put into the furnace, and again as soon as the copper flows, the lead is put in, in order to mix the metals properly.

When the operation is in good train there are three cakes for sweating at once in the furnace, each composed of a single charge; one moulded in a cast iron or lower basin, another ready to be moulded in the upper basin, and a third nearly ready to be run out of the furnace into the upper basin. The smelting of 30 cakes for sweating consumes about 12 cwt. of the best charcoal.

In the Hartz furnace, the first sweating is done upon a plain open hearth, the top of which slopes from each side to the middle and forms a gutter. In general eight cakes are sweated at once, and are separated from each other by a bit of wood about two inches long. The charcoal is heaped over the cakes, and prevented from falling by iron plates placed on the sides and front, and when the wood that separates the cakes is burned, the charcoal falls between them. The operation generally lasts three or four hours, and one cwt. and a half of charcoal is consumed. The lead melts and carries with it a considerable portion of the silver contained in the copper. If on assaying the lead it is found not to contain two and a half or three ounces of silver in a cwt. it is smelted over again with fresh black copper; but if sufficiently rich in silver, it is destined to the cupelling furnace.

After the copper cakes have been sweated on the open hearth, they are sweated a second time in a close furnace. This furnace is composed of two thin walls in the body of the furnace, which serve along with the sides to support the cakes of sweated copper, and these are the spaces between these walls in which the billets that heat the furnace are thrown. As also, vents by which the burned air that enters by openings, opposite to those in the back wall, into upright flues, which terminate in a single large chimney. The front of the furnace is closed by a large iron door.

In the Hartz, 30 cwt. of cakes that have been sweated on the open hearth, are placed in this furnace, which is then filled

Fig. 200

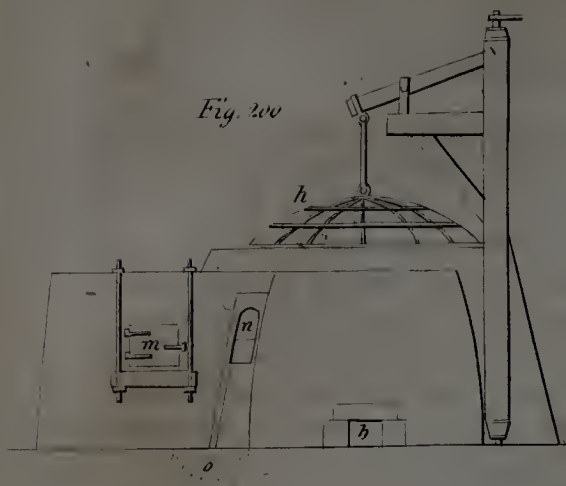



Fig. 201

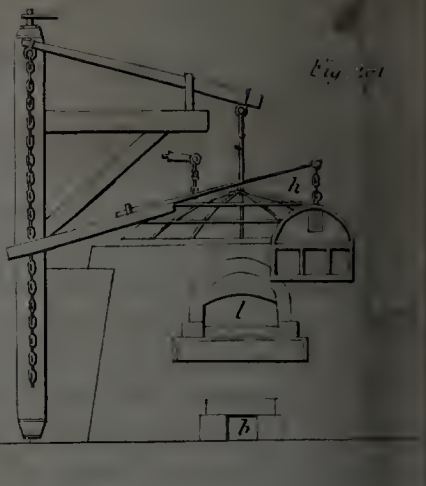
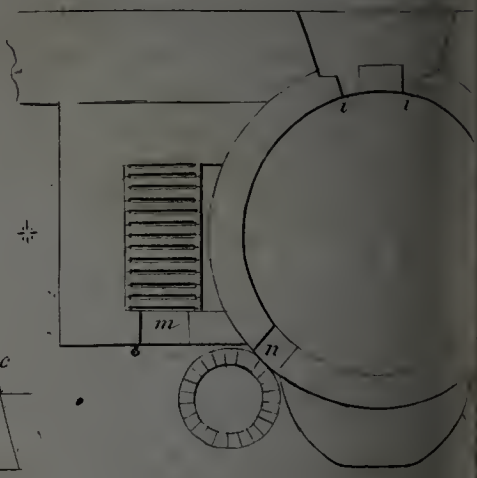



Fig. 202



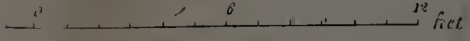




Fig. 203

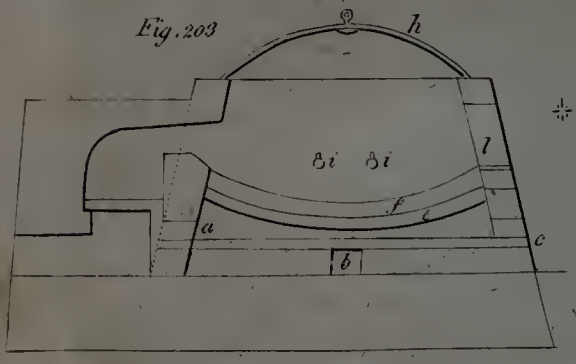



Fig. 205

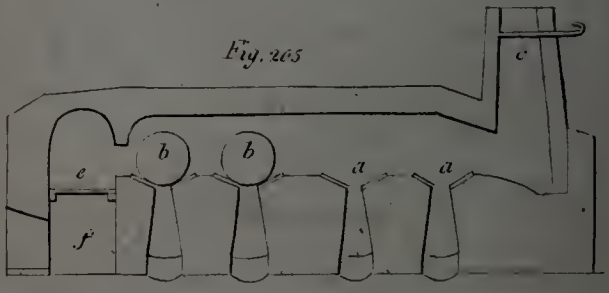
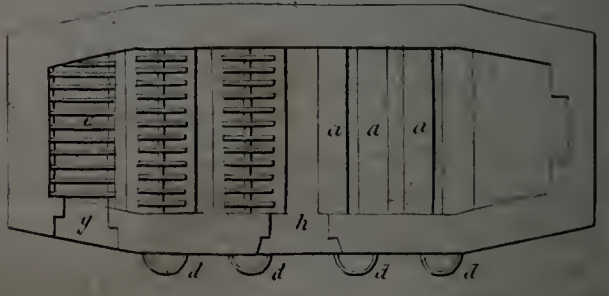



Fig. 204



vith wood and the door kept shut. About 80 or 90 cubic eet of resinous wood are consumed in the 15 or 20 hours' ining. At the end of 24 hours, the cakes are taken out, ooled in water, the fragments and silvery scales that stick to hem are struck off by the hammer, and the cakes sent to the efining house. The slags and lead that run out of the furnace re laid by, and smelted with other copper.

As much of the heat is lost in the operation when performed n an open hearth, reverberatory furnaces have been constructed in Saxony for performing it.

Fig. 204, represents the plan of this furnace, as built at Hett Staedt, in Mansfield, and fig. 205, is the vertical section in the direction * *. *A*, are the four hearths, each formed of two inclined plates of cast iron, that are united together sideways, and form the chamber of the furnace; *B*, are the cakes as they are placed on their sides on the hearth. *C*, is the chimney with its damper. *D*, are the basins into which the lead that sweats out of the copper is collected. *E*, is the grate. *F*, is the ash room. *G*, is the fire room door. *H*, is the opening into the chamber of the furnace, by which the cakes are put in and taken out.

In these Saxon furnaces 200 cwt. of sweated copper cakes are put into the furnace, which is heated with wood and a little charcoal. At the end of six hours the slags and lead are run out, and this repeated every two hours afterwards. The whole operation lasts about 26 hours, and there are consumed 1330 cubic feet of cleft resinous wood, and 15 cubic feet of charcoal. The first slags contain about 30 pounds of lead, three of copper, and two ounces of silver, in a cwt. the next contain more and more oxide of iron; the last are red, glossy, and contain 15 pounds of lead, 12 of copper, and $\frac{3}{4}$ of an ounce of silver. The cakes are then taken out, cooled in water, and the slag that sticks to them carefully separated, as it contains about two ounces of silver in a cwt. The copper cakes by this operation are reduced to about 160 cwt., and still hold nearly a $\frac{1}{2}$ an ounce of silver in the cwt.

### *Silver refined by Charcoal.*

Agatharcides says, the gold of the mines between the Nile and the Red Sea, was refined by cementation for five days with lead, salt, tin, and barley meal, the use of the barley meal was difficult to explain, until Hellot observed a similar process used in the mint at Lyons; one of the three mints from which the wire drawers of France are obliged to purchase their rods of silver. A layer of three inches of small pieces of charcoal is kept at the bottom of a crucible by a false bottom; 60 lbs. of silver in ingots are melted in this crucible, and kept in fusion for seven or eight hours. The vapour from the charcoal causes it to boil as violently as water on a quick fire, although silver alone, melted in an equal degree of heat, had only a slight motion at the surface. This mode of refining furnishes very pure silver, perfectly free from lead; the process is evidently analogous to the poling of copper and iron.

### *Silver reduced from Muriate of Silver.*

In many operations of chemistry, the muriate, chlorure, chloride of silver, formerly called Luna cornea, or horn s ver, is formed. Silver being a valuable metal, this is gen rally saved, and may be considered as an artificial ore of th metal.

To obtain the silver, the common method is to moisten t muriate of silver and form it into a ball, some pearl-ash is th put at the bottom of a crucible, the ball laid upon it, and c vered with more pearl-ash: the whole is then exposed to a gr dual heat, until the silver is reduced and melted.

The muriate of silver may be still better mixed with on fifth its weight of dry quick lime, and one-twentieth of cha coal in powder, and heated till the silver is reduced.

The silver may also be obtained by covering it with a sma quantity of water soured with sulphuric acid, or muriatic aci and putting into the water a bright piece of iron, or of zinc.

### *Silver Plate and Coin.*

In England all silver plate and coin are made of one unifor alloy, of eleven parts of silver and one of copper; which called English standard silver.

Silver plate is usually cleaned by being coated over wi whiting and water, and when the coat is dry, rubbing it c with a brush or soft piece of leather; but this does not give any polish. A paste of levigated calcined hartshorn, or lev gated bone ashes, with spirit of turpentine, used in the san manner, not only cleans the plate, but gives it a brilliant po lish. The silversmiths boil the plate along with a powde composed of equal parts of white argol, saltpetre, and alum which gives the plate a brilliant whiteness. Some use spir of salt, which causes the plate to have a black polish: thi black polish is still better given by calcined clunch of the Sta fordshire mines, called trip, which causes the plate to shin like polished steel.

In France, the silver coinage is an alloy of nine parts of si ver with one of copper, or, as they express the fineness, it con tains nine hundred thousandths of fine silver. They have als another set of coins of small value made of *billon*, which i an alloy of one part of silver, with four of copper, that is t say, it contains two hundred thousandths of fine silver. Th French table services of silver are alloys of nine and a hal parts of silver, with a half part of copper, so that it contain nine hundred and fifty thousandths of fine silver. Their sil

r toys are made of an alloy of eight parts of silver with two copper, so that they contain eight hundred thousandths of ıe silver.

A great difficulty occurs in melting silver at the mint, partly ı account of the quantity required daily, the sorting together ingots weighing 50 or 60 Troy pounds, so as to produce a ass of standard, but still more from the metal becoming finer ıring the process of melting, and thus the alloy rejected by e assay master, so that it must be remelted with worse silver, the great loss of the melter, who is paid by the pound fit r rolling.

Some of the French mints melt in forged iron pots, which sorb, the first time they are used, a part of the silver; and it suspected that they were used in the English mint during e great recoinage in the reign of William III., as the silver as then melted in parcels of 400 Troy pounds.

Other French mints, as that of Lisle, melt the silver in the ıamber of a reverberatory furnace, and taking out from time time, samples for assay, add copper as the silver refines, so to enable the melter to keep the metal to the proper stand- d during the time it is lading out and casting into bars.

In the English mint, since 1811, Mr. Morrison has succeed- l in melting 10,080 Troy pounds daily, in eight furnaces, ith eight men.

The melting furnaces are cylindrical, 30 inches deep and 21 ıches in diameter; the grate bars are moveable; the flue is ine inches square, and 45 feet high. On the grate is placed a ıst-iron cheese, concave at top, two inches wider than the ıouth of the pot, and two inches thick: this cheese is covered ı inch thick with coke dust, to prevent the adhesion of the ot.

The pots are of cast iron, of sufficient size to melt 500 Troy ounds of silver, but charged on an average with only 420: on ıe mouth of each is placed an iron ring, or muffle, six inches eep, to allow the fire to be heaped up, and also the silver in- ots to be heaped up above the rim; the cover is a flat plate of ast iron.

The pot is first put in its place, and some lighted charcoal on ıe grate, on which three inches in depth of coke are placed; hen this is lighted, three inches more are added, and thus ıe pot is so gradually heated, that it is generally two hours efore it can be brought to a charging or bright red heat. A ıass of cold iron is then held in the centre of the pot, to en- ble the melter to see if it has cracked in bringing up, as any rack would by this means be rendered visible. The pot is hen charged, coarse grained charcoal powder being added to

coat the inside of the pot, and prevent the silver from a hering. As soon as the silver melts, more charcoal powder added to the float, half an inch deep on the melted metal, a prevents its refining. When the melting is completely finishe the metal is stirred with an iron rod, the pot taken out l means of claws and a crane, and its contents poured into t cast-iron ingot moulds, which are previously heated in an ir closet with flues, and rubbed on the inside with linseed o Three meltings are worked daily in each furnace.

The ingot bars require to be annealed, by being heated redness in a reverberatory furnace before they can be rolle After rolling, the silver is again softened by a similar annea ing; boiled in very weak sulphuric acid, and dried with war saw dust.

### *Solder for Silver.*

This is made by melting three parts of silver with seven of copper, or fo of silver with six of copper.

### *Silver gilt Plate.*

Silver is gilded in the same manner as copper, but with an amalgam gold.

### *Nitric Solution of Silver.*

This is prepared by dissolving granulated silver in nitric acid, sp. gr. 1·5 diluted with an equal weight of water, until no more silver is taken up.

It is used to prepare the Lunar caustic of the surgeons, and to ascertain t presence of muriatic acid in mineral waters.

### *The Lunar Caustic.*

This mystical phrase merely denotes the salt obtained by evaporating gent the nitric solution of silver to dryness, in a silver vessel, continuing the he until it melts, and when in quiet fusion, pouring it into moulds, to cast it in sticks, the size of the barrel of a common quill.

### *Sulphate of Silver.*

This sulphate is best made by adding subcarbonate of soda to a nitric sol tion of silver, to throw down the carbonate of silver, and then dissolving th carbonate in weak sulphuric acid.

It is used to ascertain the presence of muriatic acid in mineral waters.

### *Acetate of Silver*

Is formed by dissolving in hot acetic acid the carbonate of silver, which precipitated when subcarbonate of soda is added to the nitric solution silver.

It is also used to ascertain the presence of muriatic acid in mineral waters.

### *Detonating Silver.*

This is made by putting a sixpenny piece into a flask, and pouring upon an ounce and half of nitric acid, spec. grav. about 1·35. When the silver dissolved, two ounces of spirit of wine are to be added, the liquor is careful heated over a lamp, and the detonating silver soon appears to be deposited

ite crystals. By degrees two more ounces of spirit of wine are added, and en the boiling ceases, the liquor is decanted, and the detonating silver shed by pouring water upon it, and decanting the water several times; is then to be carefully dried, with a heat not exceeding that of boiling ater.

Detonating silver explodes on being exposed to a heat above 266 deg. Fah. by the slightest shock between two hard bodies: it must therefore be maged with a wooden knife, or one of card paper.

It is used mostly for amusement, but may be applied as an alarm, by a paper glass bubble containing some of it being placed where a person is suspected going for improper purposes.

## GOLD.

The greatest part of the gold in the possession of mankind as been found in the form of sand in the beds of rivers, and separated from the other sand by washing in dishes, or on bles. This in Europe is principally done by the gipsies.

Gold ores, as they are improperly called, are only veins of lphuret of silver, holding a little gold: the mines of Mexico d Peru, as well as those of Hungary and Transylvania are of is nature. The mines of America furnish yearly about 34,500 ounds of this metal, and those of Hungary and Transylvania out 2,800 pounds.

The fineness of gold in England is estimated by reference to certain standard, being the alloy of eleven parts of gold, and ne of some other metal, and is expressed by saying that the old spoken of is so many carats, or twenty-fourth parts of a ound, so many grains, or quarter carats, and so many quarters f a grain, in a pound Troy, better or worse than standard gold.

In France the fineness of gold is expressed by stating how nany thousandth parts of the mass consist of gold.

### *Assaying of Gold Ores.*

There is properly no assaying of ores for gold in the first inance. The silver ores that contain gold, are first assayed for ne silver they will yield, and if this is sufficient to pay the harges, they are smelted and cupelled, and the silver thus obained is assayed for the gold.

Gold dust, as it is called, is assayed as gold itself, which holds little silver or copper, by first cupelling a portion of it with ead, as in assaying silver, and then flattening the bead, rolling up, and then examining the quantity of gold in this plate.

When the silver to be examined contains but a small quantity f gold, of which a judgment may be formed by rubbing it on ne touchstone, a little of it previously rolled out, is dissolved n nitric acid, when the gold contained in it is left behind unissolved, in the form of a brown or black calx, which is heatd until it acquires the proper colour of gold, and then weighed.

But when there is a greater quantity of gold in the sample th of silver, the gold is separated from the silver as perfectly can be done, by solution in aqua regia.

In the first case, however, a residuum or arrearage of silv remains behind, united with the undissolved gold, and in the s cond instance a residuum of gold is left in the undissolved s ver. The cause of this is, that gold and silver defend each oth mutually from the action of the menstruum, when part of t one is enveloped in an exceeding small quantity in the other.

These arrearages, according to Schluter and Cramer, scarce amount to one one-hundred and fiftieth or one two-hundred of the mass. By this observation it has been discovered farthe that neither aqua fortis nor aqua regia can effect a perfect separ tion in an alloy of gold and silver, unless these metals be mixe together in a certain proportion. But when one part of gold alloyed with three parts of silver, silver may be dissolved b nitric acid, properly diluted, so that only the gold, with a ver small arrearage of silver, shall remain behind undissolved. Th is called separation by quartation, or simply quartation.

Now, in order to attain this end, the quantity of gold co tained in the silver must first be ascertained by the touchstor In case that the gold should amount to more than one-fourth, much silver must be added to the mass, and fused with it, as sufficient to produce the above-mentioned proportion; and th the quarted metal is rolled out, dissolved in nitric acid, the r siduum of gold heated to recover its proper colour, and weighe

The separation of platinum from gold, is effected by pourin into a solution of this alloy, made by a mixture of nitric ac with the muriatic, a solution of sal ammoniac, when the platin is precipitated alone, after which the gold, may be thrown dow separate by copperas water.

## *Extraction of Gold.*

As gold is not extracted direct from its ores, but from silve which contains a certain portion of it, or from gold dust, th processes for extracting it are the same as those of assaying fo gold: except in the parting by means of sulphur, or dry par ing, as it is called, used in the Hartz, which cannot be performe upon a small quantity of materials.

When a metal contains a large proportion of gold, united wit silver, copper, or lead; the gold is separated from the lead an copper by cupellation, and from the silver by parting.

By these means the gold is obtained from the metal obtaine from poor gold holding metal, by means of sulphur and litharg as already related; also from the native gold dust collected fro the sands of rivers, by the negroes of the Gold Coast of Afric

ıd by the gipsies of Europe; and from old gold plate, coins, d trinkets of that metal.

If the gold contains no silver, which is rarely the case, cu-llation alone, with a proper quantity of lead, as in the case of lver, is sufficient; but if the metal contains silver, it is neces-ry first to get rid of the copper and lead by cupellation, and en manage the matter so that the metal may contain one-quar-r in weight of gold, and three-quarters of silver: an operation hich is called quartation. If the silver is in too large quanti-, part of it must be removed by means of sulphur, and if it in too small quantity, a sufficient quantity of pure silver must e melted with the metal, and then the quarted metal may be arted with aqua fortis.

The gold being quarted, is separated from the silver it con-ins by parting with aqua fortis. For this purpose, in a large ay, it is melted, and being ladled out with a small three-cor-ered crucible, it is poured in a fine stream into cold water, and ius reduced to grains.

About six pounds of this granulated gold is put into a glass olthead, the bowl of which is coated with clay; and this being laced in a sand bath, aqua fortis is poured in, so that the gold entirely covered. A gentle heat is applied, and when the id appears to be saturated, it is drawn off, and fresh poured on, ntil it has no action on the metal. The fire is then withdrawn, nd when the furnace is cooled, the remaining gold is washed vith hot water, until the water comes off tasteless: the washings re collected together in a copper basin, and salt added to sepa-ate the silver they contain, as muriate of silver; the washed old is carefully dried, melted with a strong fire, and cast in in-ots: it is 23 carats eight-twelfths fine, and very ductile.

The aqua fortis that is drawn off, is distilled in glass retorts. The distillation in the Hartz works lasts several days. The fire s at first very gentle; when red vapours appear, the appara-us is luted, and the fire increased. Towards the end, some itrate of silver sublimes in whitish flowers, adhering very fast o the neck of the retort. The distillation being finished, the etort is broken, the flowers and glass to which they stick are nelted with a little litharge, and thus a button of silver is ob-ained. The residuum of the distillation is carefully collected, nd together with the button just mentioned, is added to the ead obtained in remelting the sulphuretted iron, arising from eparating sulphur from silver by iron, and cupelled, as already tated: the product is fine silver.

As the silver obtained by cupellation from the lead and cop-per ore of the Hartz mines contains a very minute portion of gold, this is separated by means of sulphur or dry parting.

The silver is melted in portions of 100 or 150 pounds in black melting pot, kept melted about two hours, ladled out wit a small crucible, and poured into cold water kept stirred. Th silver thus granulated is distributed into wooden dishes, an dusted with one-eighth its weight of sulphur: the grains ar then shaken to distribute the sulphur equally.

On remelting this silver it divides itself between the sulphu and the gold; the sulphuretted silver swims at top, and the al loy of gold and silver. When the mass is perfectly liquid about one-sixteenth or one-twelfth of litharge is strewed on th surface; the litharge is reduced, and part of the lead unites witl the sulphur, while another part uniting with the silver thus se parated from the sulphur, passes through the melted sulphuret and carries down with it into the metallic button any particle of gold that remain suspended in the sulphuretted silver. Th crucible is left to cool, and then as the separation of the buttor is not distinctly marked, the sixth part of the height of the in got is struck off, and laid aside.

The sulphuretted silver, or upper part of the mass, is remelt ed with fresh sulphur, and only one-thirty-second of litharge The sulphuretted silver obtained in this second melting is as sayed, and if it contains ever so little gold, it is melted a thir time with fresh sulphur and litharge. The buttons struck off i these remeltings are added to the former.

The buttons of impure gold thus obtained, are melted toge ther, granulated, and again worked with sulphur and litharge a at first, until, by assaying the button, it is found to contain no more than five or six parts of alloy, partly silver and partly lead to one of gold: at which time the metal is generally reduced tc 15 or 20 pounds. The gold is then refined by cupellation, quarting, and parting by aqua fortis, as in other cases.

The masses of sulphuretted silver are every six months col lected, and melted in large crucibles with one-fourth their weigh of iron, and left to cool. The upper part of the mass is sul phuretted iron, the lower is composed of six-sevenths of silver and one-seventh of lead, which are separated by cupellation. The sulphuretted iron is remelted with one-tenth of iron, and when completely liquid, dusted over with litharge, which is re duced and the lead falling through the melted mass carries with it a small portion of silver. The button thus obtained is cu pelled separately along with the refuse matters of the parting, and yields fine silver. The sulphuretted iron that swam over this button is mixed with the broken crucibles and other refuse matters, as also the impurities arising in the last-mentioned cu pellation, namely, the litharge, bed, and scum, are smelted, and yield a button of lead, which is cupelled, and the silver reserved

d added to the next parcel of raw silver that is to be operated on. The impurities of this cupellation are laid aside, and ded in the smelting of the next parcel of sulphuretted iron.

By this series of operations, there are annually separated ith some profit four or five pounds of gold, from more than 0,000 cwt. of ore.

Another mode of separating a small portion of gold from a rge portion of silver is now in use among the refiners at aris.

As fast as any new parcels of silver are brought to these re-ners, they proceed to separate the small quantity of gold, hich would otherwise be neglected, and which they estimate on an average to be one-tenth per cent. of the weight of the lver. Now if the many thousand ounces of silver which are nually melted, are calculated, it will easily be seen how much old is thus procured, which would otherwise be left in the lver, and lost to the world and its owner.

Upon a number of stove holes, of a foot in diameter, there e placed platinum eggs, each of which contain 6lbs. of gra-ulated silver, and 12lbs. of oil of vitriol. All these eggs are overed with a high cap of the same metal, with a small open-g, a quarter of an inch over, at top, to let out the vapours. hese stoves are arranged under a hood, which opens into the himney of a furnace, in which a fire is kept for the purpose f producing a strong draught of air from the hood into the ue, to carry off the vapours.

As the sulphuric acid does not act upon silver, unless heat is pplied, a fire is lighted in each of the stoves; at first the solu-on goes on very fast, and much sulphurous acid gas is disen-aged, but after two or three hours, the solution goes on slower, nd it requires 15 hours in general to complete the solution.

The vapours exhaled in this dissolution of the silver, is not nly sulphurous acid gas, but also those of sulphuric acid itself; nd in order to prevent them from having a hurtful effect on the ealth of the operators, it is adviseable to fit a pipe of platinum r glass, to the hole in the cover of the eggs. It has been pro-osed indeed that the eggs should be covered with heads, con-ected with receivers, in which the sulphuric acid might be ondensed.

The silver being dissolved, the solution is poured out of the latinum eggs into stone ware pans, and water is added so as to educe its density to 15 or 20 deg. of Baumé's hydrometer, r so that a bottle holding a pound avoirdupois of water, shall old about 18 oz. or 18 oz. and a half of the solution. The olution is then left for some time to settle, and being carefully oured off the brown powder, which is in fact the gold con-

tained in the silver; slips of copper are added, and the silv which is separated by the copper is carefully washed.

The silver obtained is melted in a crucible, and run into i gots.

The brown gold powder is mixed with a little saltpetre, an melted,—the use of the saltpetre is to separate any portions copper that may be contained in it.

The blue solution that is left after the precipitation of t silver being a sulphate of copper, may be evaporated and cry tallized, the fine large crystals picked out for sale, and t small dissolved again in water, and crystallized: or it may employed in the preparation of various colours.

This is the process actually used at present by the Frenc refiners, instead of the usual mode by aqua fortis.

### *Gold refined by Antimony.*

The grain gold obtained in parting by aqua fortis still co tains a small portion of silver, which injures its colour: hen in some mints, as in those of Holland, the gold is still farth refined with antimony. The gold is melted with twice weight of sulphuret of antimony, in a covered crucible with strong heat, and poured out into an ingot cone: the regulus separated from the antimony that lies at the top, and is aga melted a second and third time, if it was very impure, with less quantity of sulphuret of antimony. The regulus is th melted in a large crucible, and the blast from a pair of bellow directed upon the surface, to evaporate the antimony; whe the vapours cease to arise, a little refined nitre, or nitre an borax, is thrown upon the gold, and it is poured out. If th gold cracks under the rollers, it is melted again, and a littl more nitre and borax flung upon it.

### *Gold refined by cementation.*

Although the cementation of gold is more usually employe to extract the alloy of copper or silver from the surface of gol toys, and thus give them the appearance of a greater degree fineness than they really possess; yet it is still used in som mints, as in that of Venice, and probably in that of Constant nople, and in those of other eastern countries.

The gold to be refined in this manner is rolled out into ex ceedingly thin plates, or granulated and laid in beds along wit a mixture of four parts of brick dust, one of copperas calcine to redness, and one of salt, in a deep crucible, the bottom an top bed being of the cementing powder, the crucible is the

vered, the joints luted with clay, and exposed to a heat raised adually, and finally kept up at a red heat for 18 or 24 hours. he crucible being then let to cool, the gold is separated from e cement and washed with hot water.

### *Gold Coin and Plate.*

The gold coin of England is made of gold made standard by ual parts of silver and copper.

Gold is melted in the English mint in parcels of 90 to 105 roy pounds, in foreign black lead pots, which are less liable crack in the fire than the English. The air furnace is 14 ches square, and 20 inches deep, with the bars of the grate oveable. A stand cut from the bottom of an old pot, and out an inch and a half thick, is placed on the grate, and co-red with coke dust. On this the melting pot is placed, and vered with another pot cut horizontally in half. A little ghted charcoal is placed on the grate, and about four inches ep, of coke on this; the draught up the chimney is totally opt by a damper, so that the fire is brought on very gradually. hen the coke is all alight, the furnace is filled with more ke up to the height of the wider ring of the covering t, or muffle as it is called. As soon as the pot is thus brought a bright red, the draught up the chimney is opened, and the t charged with the gold, which takes about an hour to be-me melted. It is then stirred with a black lead rod previ-usly heated to a bright red. A grate bar on each side of the t stand is then drawn out, the fuel forced into the ash room, e pot taken out with vertical or melting furnace tongs, placed n the top of the furnace, then removed with horizontal or ind furnace tongs, and its charge poured into the ingot moulds, form bars ten inches long, seven wide, and one thick. The ot is then returned to the furnace, the grate bars replaced, as so the fuel, and the pot re-charged. By proper care, a pot ay be used eight or ten times in the course of a day.

The bars of gold do not require annealing to enable them to and the action of the rollers.

The forge used by the Ceylonese goldsmiths deserves to be known, and may e useful to a practical chemist, when he wishes to use a small fire, and has no rge, but only a blow-pipe at hand. The Singalese forge is only a small low ear-en pot full of chaff or saw-dust, on which he makes a little charcoal fire, which e excites with a small bamboo blow-pipe, about six inches long, the blast being irected through a short earthen pipe or nozle, the end of which is placed at e bottom of the fire. It is astonishing what an intense fire, stronger than is equired to melt gold or silver, can be brought up in a few minutes. The suc-ess probably depends on the bed of the fire being a combustile material, and very bad conductor of heat.

### *Green Gold.*

This shade of colour is obtained by melting 708 grains, one ounce nine pennyweights and a half of pure gold, wit 292 grains, or 12 pennyweights and four grains of pure si ver.

### *Nitro muriatic solution of Gold.*

For making this solution, four ounce measures of muriat acid are mixed with one ounce measure of nitric acid, and a ter the acids have been mixed some hours, grain gold, as fir or pure gold is called by the refiners, is added, until no mo is dissolved.

Nitro-muriatic solution of gold is used to make Cassiu purple precipitate, to gild metals by the rag, as also to gil steel.

### *Cassius' purple Precipitate.*

This precipitate is made by dissolving a few grains of tin muriatic acid; diluting the solution with a large quantity distilled water, as a gallon to a dram measure of the solutio and dropping into the diluted liquid 20 or 30 drops of the n tro-muriatic solution of gold to each gallon. In the space three or four days, a purple precipitate or slime will be fou at the bottom of the vessel. The liquid being filtered, t precipitate is washed with water, and dried.

Cassius' purple precipitate is used to colour glass of a purple colour, wh melted in open vessels: in close vessels it gives no colour.

### QUICKSILVER OR QUIK,

Writers of chemical books usually call this metal quicksilve but workmen frequently denote it by the name quik.

There are two kinds in the market.

*Spanish quicksilver*, packed in bladders, which are enclos in small barrels, and these again in chests.

*Austrian quicksilver*, packed in cast-iron bottles, and i ported partly through Holland, and partly from Trieste a Venice.

Both are very pure; workmen who use it can so readily di cover the slightest addition of any other metal, by pouring from one hand to the other, that it would be useless to off any quik to them unless it were pure. The source of the in pure quicksilver in the apothecaries' shops, is the purchase the quik from the silvering tables of bankrupt or deceas

looking-glass makers, which is of course impregnated with tin, and sometimes lead and bismuth; this quicksilver is cheaper than the pure, and is thought by them good enough for making blue pill and blue ointment.

### *Dutch Vermilion.*

There are two kinds of vermilion in the shops; the Chinese vermilion, or hartall, which is a sulphuret of arsenic, and the Dutch vermilion, which is a sulphuret of quicksilver.

The Dutch manufacture their vermilion, by grinding together 150 pounds of sulphur, and 1080 of quicksilver, and then heating the Æthiops mineral thus produced, in a cast-iron pot, 1 feet $\frac{1}{2}$ in diameter, and 1 foot deep. If proper precaution is taken, the Æthiops does not take fire, but merely clots together, and requires to be ground. Thirty or 40 pots, capable of holding 24 ounces of water each, are then filled in readiness with this Æthiops.

The subliming vessels are earthen bolt heads, coated two-thirds of their height with common fire lute, and hung in the iron rings, at the top of three pot furnaces, built in a stack under a hood or chimney, so that the fire has free access to the coated part; each sublimer has a flat iron plate, which covers the mouth of it occasionally. The fire being lighted in the evening, the sublimers are heated gradually to redness. A pot of Æthiops is then flung into each sublimer; the Æthiops instantly takes fire, and the flame rises four or six feet high; when the flame begins to diminish, the sublimer is covered for some time. By degrees, and in the course of 34 hours, the whole of the Æthiops is got into the sublimers, being 410 pounds into each.

The sublimers being thus charged, the fire is kept up, so that on taking off the cover every quarter or half hour, to stir the mass with an iron poker, the flame rises about three or four inches above the mouth of the sublimer. The sublimation usually takes 36 hours, and when the sublimers are taken out of the furnace, cooled, and broken, 400 pounds of vermilion are obtained from each.

Berzelius, who calls it *bi sulphuretum hydrarggri*, or Hg $S^2$, makes the atomic weight 2,933,920. Dr. T. Thomson also considers it as Hg $S^2$, but calls it *per sulphuret of quicksilver*, and its weight as 29,000.

### *Turpethum Minerale, or Queen's Yellow,*

Vulgarly called, from the contracted manner in which druggists' bottles are labelled, turpeth mineral.

It is made by heating one pound of quicksilver, with six or seven pounds of oil of vitriol, to dryness, and then throwing this white mass into a large quan-

tity of hot water, by which means the deuto sulphate of quicksilver, as t white mass is called, is separated into sub deuto sulphate of quicksilver, or t turpethum minerale, which settles in the form of a beautiful yellow powder, a into acid deuto sulphate of quicksilver, which dissolves in the water, and eve trace of which must be removed from the turpethum by plentiful washing.

The suffocating fumes of sulphurous acid, which are emitted in large quan ty in this process, require it to be performed under a hood, through whic strong draught of air is made to pass.

To avoid this inconvenience, the quicksilver may be add to strong nitric acid, kept hot until the effervescence and r vapours of nitrous gas cease, but no longer. Glauber's sa equal in weight to the quicksilver, is then to be dissolved in large quantity of hot water, and the nitric solution of quic silver poured into it; the liquid is then filtered, and the turp thum left on the filter washed.

Turpethum minerale forms the active ingredient in what is called *eye sn* for man or horse; and it is also used as a bright yellow colour.

According to Dr. T. Thomson, who calls it *neutral per sulphate of quicksil* it is S:· Hg:, and its atomic weight, of course, 32,000.

### *Nitric Solution of Quicksilver.*

Nitric acid, diluted with three times its weight of water, slowly dissol quicksilver, without any application of heat.

This cold solution mixes with pure water without any diminution of tran rency; but if 4 gallons of water contain only one grain weight of muriatic a a drop or two of this nitric solution will produce a slight dull tinge. Or if f pounds of water contain only one grain weight of ammonia, a drop or tw the solution will produce a slight blackish yellow tinge.

This solution may also be used to discover phosphoric acid; the se li n thus produced is taken up again, by adding more phosphoric acid, or nitric which is not the case with the sediment produced when muriatic acid is cause.

### *Red Precipitate.*

This is an oxide, or sub-nitrate of quicksilver, prepared means of nitric acid; but although this oxide, if it may be called, can be easily prepared for private use, there is con derable difficulty in giving it the peculiar scaly appearan of the Dutch red precipitate, which is probably all made Idria.

The common process is to dissolve quicksilver in stro nitric acid, taking care to add no more quicksilver to the a as soon as the red vapours cease. The solution is then evap rated to dryness; and the dry mass calcined in a broad shall dish, until it no longer emits red vapours; but this has not t proper scaly appearance required in the market.

A process is given, which is said to give this marketa quality: six pounds of quicksilver are to be dissolved in t pounds of aqua fortis, and the solution kept on warm sand

wo or three days. One half is then poured into a large retort r rather body, and distilled to dryness. The mass being aken out, is divided amongst six retorts, placed on a sand eat; the remaining half of the solution is also divided amongst hem, and after some hours' digestion, the whole is distilled to ryness. The aqua fortis that comes over in these distillaions is used in the next operation, adding about a quarter of resh acid.

The dry masses thus obtained, are put into three retorts, laced in separate sand pots, and furnished with receivers, the res are so managed, that in the first three hours some flowers hould settle in the arch of the retorts; in the next three hours, hey should be driven into the neck; and in the last three ours, the mass in the retorts should appear first yellow, then range, and lastly vermilion red; the fires are then to be stopped, and when cool, the red precipitate, it is said, will have the proper scaly appearance.

As this scaly appearance is supposed to proceed from a very minute proportion of corrosive sublimate, diffused through the mass, some chemists have directed that the nitric acid it should be made with, should be distilled from a very small proporion of salt: namely, 1 Troy lb. of acid, from an apoth. dram of salt.

### *Fulminating Quicksilver.*

This can only be prepared in small quantities, not exceeding an ounce at a time, on account of the danger of explosion.

100 grains, or 1 dram 2 scruples of quicksilver, are to be dissolved without heat in 1½ ounce measure of nitric acid, the solution poured upon 2 ounce measures of spirit of wine, and heat applied until the liquid begins to effervesce. A white powder collects at the bottom of the flask, which is, without loss of time, to be put upon a filter, well washed with distilled water, and dried in a water or steam bath.

Mr. Wright says, many sportsmen give it a preference, as a priming for percussion guns, over the mixture of oxymuriate of potasse and sulphur, because it requires a harder blow to inflame it, and it is not liable to spontaneous explosion. It is suspected that it will wear the nipples in which the caps are placed, faster than the oxymuriatic priming, but this might be obviated by making the inner part of the nipple of platinum.

### *Corrosive Sublimate.*

The theoretical chemists have given a number of new names to this salt, as *corrosive muriate of quicksilver*, *oxymuriate of quicksilver*, *muriate of oxidated quicksilver*, and still more lately, *deuto chloride of quicksilver*, and *deuto chlorure of quicksilver*.

This was first manufactured at Venice, and hence long called Venetian sublimate. They grind 400 pounds of copperas, calcined to redness, 200 of saltpetre, 200 of salt, 180 of quick-

silver, 50 of the residuum of some former operation, and al the impure sublimate, generally 20 pounds; of the last opera tion, moistening the whole with some of the acid that had dis tilled over on some former sublimation, and sublime it in glas bolt heads, covered with heads, and fitted with receivers, se in a sand heat, under which are several fire rooms.

Kunkel, in 1722, proposed to make corrosive sublimate b boiling two pounds of quicksilver in an equal weight of oil o vitriol, to dryness, and when the mass was cooled, to grind i with three pounds and a half of salt, and sublime as usual.

This process is that now used by the manufacturers:—5( pounds of quicksilver are put into a cast-iron pot or dish along with 60 pounds of oil of vitriol, and the pot being se upon a furnace, or, which is still better, on account of the suf focating fumes, placed in the chamber of a reverberatory fur nace. The mixture is gradually heated; until a sample of th thick white mass being taken out, and thrown into some pearl ash water, turns of a clear yellow colour, without any admix ture of blackness. The fire being then withdrawn, and th mass cooled, it is ground with 50 pounds of salt, and 1 pounds of black manganese, left for two or three days, drie with a gentle heat, then divided into several bolt heads, an sublimed on a sand heat.

There is considerable difficulty in managing the fire at th end, so as to procure all the corrosive sublimate, and yet hav it in a solid cake, for the least excess of heat melts some of i and it runs down.

When the sublimate is not for sale by wholesale, the metho proposed by Homberg, in Mem. d l'Acad. for 1709, is to b preferred. He advises, that instead of being sublimed in bol heads, it should be distilled with a very quick fire from a ver low retort, having a short wide neck, into a large receiver the greater part will come over in the form of fine white snow He found, that in consequence of the newly condensed subli mate, being liquid, it was continually running down, and ha got to be raised over again; so that it took 12 hours to sublim three pounds of sublimate in a bolt head; whereas, in a retort six pounds came over in only two hours.

Corrosive sublimate is the *murias hydrargyricus*, of Berzelius, or Hg' M' and its atomic weight, 3,416,900. Dr. T. Thomson calls it *per chloride quicksilver*, or Cl Hg, and its weight 34,000.

## *Calomel.*

This, which is the *sweet sublimate* of the old chemists, ha received a number of names lately, as *mild muriate of quick silver, muriate of quicksilver, muriate of oxydulated quick*

*lver;* and of late, those of *proto chloride of quicksilver*, and *roto chlorure of quicksilver.*

The old process for preparing calomel, and which is still fol-owed in general medical laboratories, is to grind quicksilver ogether, with an equal weight of corrosive sublimate, moist-ned with a small quantity of water, until they are thoroughly ixed, and then sublime the mass in bolt heads. As corrosive ublimate is a most violent poison, and calomel is used only as medicine, and in modern practice more frequently than any ther, the sublimed mass is powdered, and very carefully ashed, with a large quantity of warm water; calomel being early totally insoluble in water.

The manufacturing chemists now use nearly the same pro-ess for calomel as for corrosive sublimate; using, however, nly two-thirds the quantity of oil of vitriol in the preliminary rocess, and stopping as soon as the black colour struck by the roto sulphate of quicksilver, with sub carbonate of potasse vater, is of a full black, and before it acquires a yellowish inge. In the sublimatory part of the process, the black man-anese is omitted, and a stronger fire used. The calomel ob-ained is ground to powder, well washed, and assayed with ure caustic potasse water, with which it strikes a deep black olour; whereas corrosive sublimate produces with the same vater a reddish yellow.

Calomel, for medical purposes, ought to be in the state of he finest powder; and Mr. Howard, following the steps of Homberg, has effected this by chemical means in a manner su-perior to the mechanical division. This he performs by dis-tilling the mixture for calomel in low retorts, into double necked, quilled receivers, kept filled with steam, the vapour of the calomel, being prevented from condensing in the arch or neck of the retort by the heat, no sooner meets the steam than it immediately becomes solid, and takes the form of an impalpable white powder: common powdered calomel is of a dead yellowish white.

Calomel is the *murias hydrargyrosus* of Berzelius, or $Hg \cdot M$, and its atomic weight, 2,974,250. Dr. T. Thomson calls it *proto chloride of quicksilver*, or $Cl\ Hg^2$, and its weight 29,500.

## *Silvering for Looking Glasses.*

Looking glasses are silvered by an extemporaneous amalgamation of tin and quicksilver. Tin foil is placed on the back of the glass, and some quicksilver is poured upon it, and spread over the surface with a hare's foot. Another glass is then slid over the tin, to drive off part of the quicksilver; and paper and a board being laid on the tin, it is strongly pressed with a

number of weights, to expel, by degrees, the superfluo quicksilver, and leave only a crystallized amalgam on the ba of the glass.

### *Silvering for Globes.*

This amalgam is made by dissolving one pound of tin gl or bismuth, in four pounds of quicksilver. The globes to silvered are thoroughly cleaned on the inside, and warme then the above amalgam being heated, so as to be perfectly quid, is poured in by a paper funnel, and the globe inclin in various directions, that as the amalgam crystallizes by co ing, it may adhere to all parts of the globe; the superfluo amalgam is then poured out.

## SPELTER OR ZINC.

Of this there are several kinds in the market.

*German spelter*, or *spiauter*—it is not esteemed pure.

*Tutenag*, *calain*, or *Indian zinc*—imported in thin r tangular plates, 8 or 9 inches long, $5\frac{1}{2}$ wide, and $\frac{7}{8}$ inch thic it is very brittle. It is esteemed very pure.

*English*, or *Bristol zinc*—in blocks, ingots, and bars different weights.

*Rolled*, or *sheet zinc*—made by rolling English zinc.

*Zinc wire*, and *zinc turnings*, are also to be obtained the metal warehouses.

Spelter was originally obtained as a secondary product in the smelting of lead ore found near Goslar, and as it dropped in the form of nails, the m has also received this name—*zinken*.

What spelter is, or what uses are already made of it, Mr. Mason, in the P losophical Transactions, for 1747, professes not to know; but he believe was never yet applied to so large a work as the cylinder of a fire engine, Mr. Ford, of Coalbrooke Dale, in Shropshire, did it with success. It ran ea and cast as true as brass, and bored full as well, or better, when it had b warmed a little. While cold, it is as brittle as glass; but the warmth of hand soon made it so pliant, that he could wrap a shaving of it round his fin like a bit of paper. This metal never rusts; and therefore works better t iron, the rust of which, or the least intermission of working, resists the mot of the piston.

### *Extraction of Spelter from its Ores.*

The process for obtaining spelter or zinc, by distillation, said to have been introduced from China into England, whe the manufactory was first established at Bristol.

Fig. 206, represents the plan of the zinc furnace, and fig. 207, the verti section of the same. In these figures, *a*, is the grate of the furnace, supp ing the coals used for fuel, and *b*, is the ash room. *C*, *d*, *e*, *f*, *g*, *l*, are arches; under the floor of the fire room, which is filled with six cast-iron c cibles, *i*, to receive the calcined ore that is to be distilled. Fig. 208, is a v tical section on a scale of twice the size of one of these crucibles; and fig. 20

a cast-iron pipe, that is fitted to the bottom of these crucibles. *K, l,* are small chimneys, furnished with registers, *m*, that regulate the draught of through the furnace. *N*, are six tubs, filled with water, into which the elter that is distilled drops, and is congealed.

The ore, if very pure, is only stamped, but if mixed with rthy or stony matters, it is stamped in a current of water, d washed. The ore is then roasted in the chamber of a re-rberatory furnace, about 10 cwt. at a time, the fuel is coal, d the operation is continued for about four or five hours. fter this, the roasted ore is mixed with one-seventh of its eight of charcoal dust, and the crucibles are charged with the ixture; for this purpose, the cover is taken off, the mouth of e pipe that passes through its bottom, closed with a stopper f clay, and the charge introduced by the opening in the roof the furnace over the crucible, which is afterwards covered, d the joints luted, the clay stopper to the pipe being previ-sly removed.

Fire is then applied, and when the brown blaze that appears the mouth of the pipe, owing to the combustion of the cad-ium, contained in the ore, which, as the most volatile of the vo metals, rises first, is succeeded by a blue blaze, indicating e distillation of the spelter itself; another cast-iron pipe, aching nearly to the surface of the water, is fitted to the end f that which is fixed in the crucible; the burning of the zinc eing thus prevented, it falls in drops into the tubs of water. he whole operation, including the charging and emptying of e crucibles, when the furnace is cool, generally takes up five ays. The zinc obtained, is afterwards melted in an iron pot, s surface being kept covered with charcoal dust, to prevent xidation; and ladled out into iron moulds.

Ten cwt. of ore generally produces 4 cwt. of spelter or zinc, vith the expense of 115 cubic feet of pit coal. The annual roduce is about 4000 cwt.

Blende may also be distilled in this manner for spelter; but t has been found more advantageous to use it in the manufac-ure of brass.

Several patents have been taken out for improving this pro-ess, particularly in respect to the form of the pipe in the cru-ible; but the old method is still preferred by the manufac-urers in England.

Mr. Dillinger's improvements in this process have, how-ever, spread considerably in Germany, and the neighbouring countries.

Fig. 209, represents partly the section, and partly the elevation of these furnaces; and fig. 210, the plan of four of them, as they are connected together. *A, b, c, d,* are the fire rooms of these furnaces, with their ash rooms; grates, or pierced vaults, and doors. *E, f, g, h,* are the charging doors of the

chambers of these reverberatories, upon the floors, *m*, of which are disp a great number of baked earthen long pots, about five feet long, and six i wide, closed at top, open at bottom, and filled with the prepared zinc ore. are side openings, by which the flame that had passed into the ch through the openings, *k*, vents itself into the hollow space between the naces, and from thence into the chimney, *t*, which serves for the whole *M*, *n*, are earthen pipes, open at both ends, and shaped like the capita a column, the pipes are hung quite close together, in a grating of iron l that form the real floor of the chamber; but as the square heads of these p overlap the bars, and meet together, they form the floor that is actually posed to the heat. A groove, in the edge of these pipes, *m*, receives open end of the long pots, *p*, and the prepared ore is prevented from fall out, by some large pieces of charcoal which are stuck in the mouth of the l pots. *R*, are sheets of rolled iron, placed below the floors of the chambe receive the drops of zinc that distil down from the short pipes, *m*, *n*. *S*, sheets of rolled iron, hung before the vault under the floor of the chamber hinder a draught of air on the zinc as it drops from the pipes, as that drau would cause the zinc to take fire. *T*, is the chimney of the whole stack four furnaces.

Each of these furnaces are, according to the plan, made 160 pots, in 10 rows of 16 pots each, but only 84 of th charged with ore, are put into the furnace, along with a su cient number of unbaked empty pots, to supply the place those that break in the operation, which is usually about or 30.

The 64 pots of the first four rows next the fire room, charged with a mixture of 14 cubic feet, or 1820 pounds stamped and roasted calamine, 36 cubic feet, or 504 pounds bruised charcoal, passed through a sieve whose meshes only $\frac{1}{8}$ inch wide, 36 pounds of common salt, and 4 cubic fe or 280 pounds of water containing 3 pounds of potash in so tion. Only 20 pots are placed in the two next rows, t spaces of 12 pots being left empty. These pots are charg with a mixture of four cubic feet, or 520 pounds of stamp and roasted calamine, 16 cubic feet, or 224 pounds of sm pieces of charcoal, pass through a sieve whose meshes are inch wide, 16 pounds of common salt, and one cubic foot, 70 pounds of water holding $\frac{3}{4}$ pound of potash in solutio As each of the pots hold 771 cubic inches, or about 20 21 pounds of the mixture, the above quantity is the char for two of these furnaces, which are usually heated at onc while the other pair are cooling.

The furnaces are heated with beech billets, and the firin which lasts from 30 to 36 hours, consumes about 72 cub yards of wood. The 2340 pounds of roasted calamine in t above charge, produces about 800 pounds of raw spelte which is received on the sheets of iron, and being afterwar melted to be cast into ingots, yields about 700 pounds of pu zinc, and about 150 pounds of oxide, which is mixed with t calamine in the next operation.

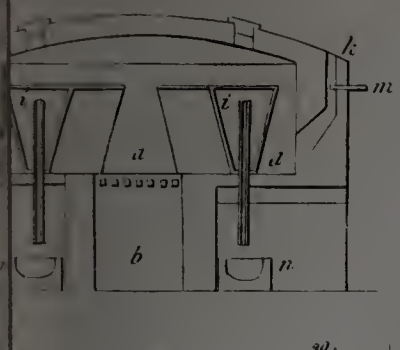



Fig. 206

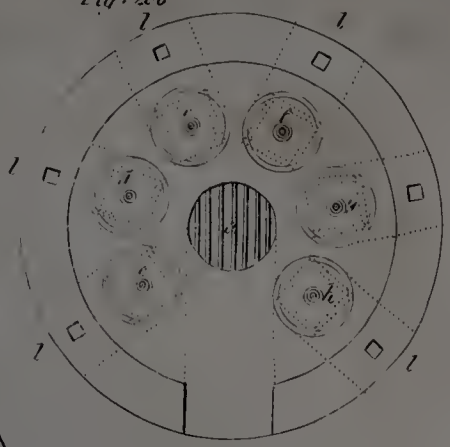



Fig. 208

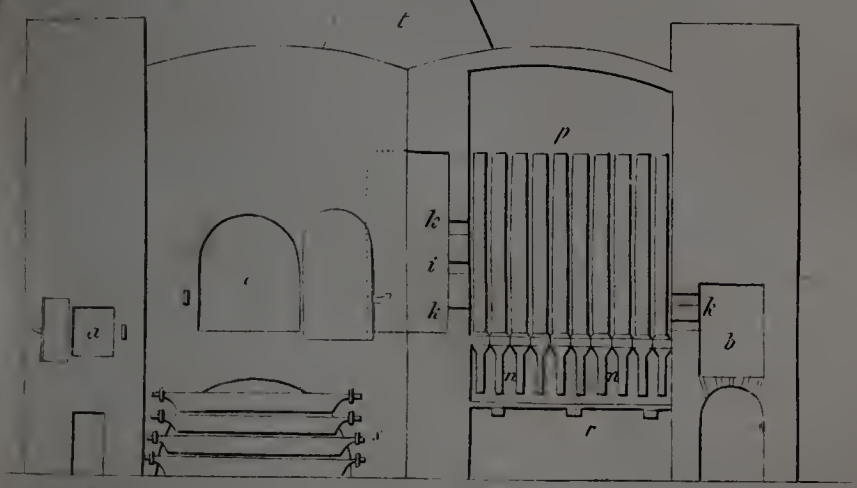
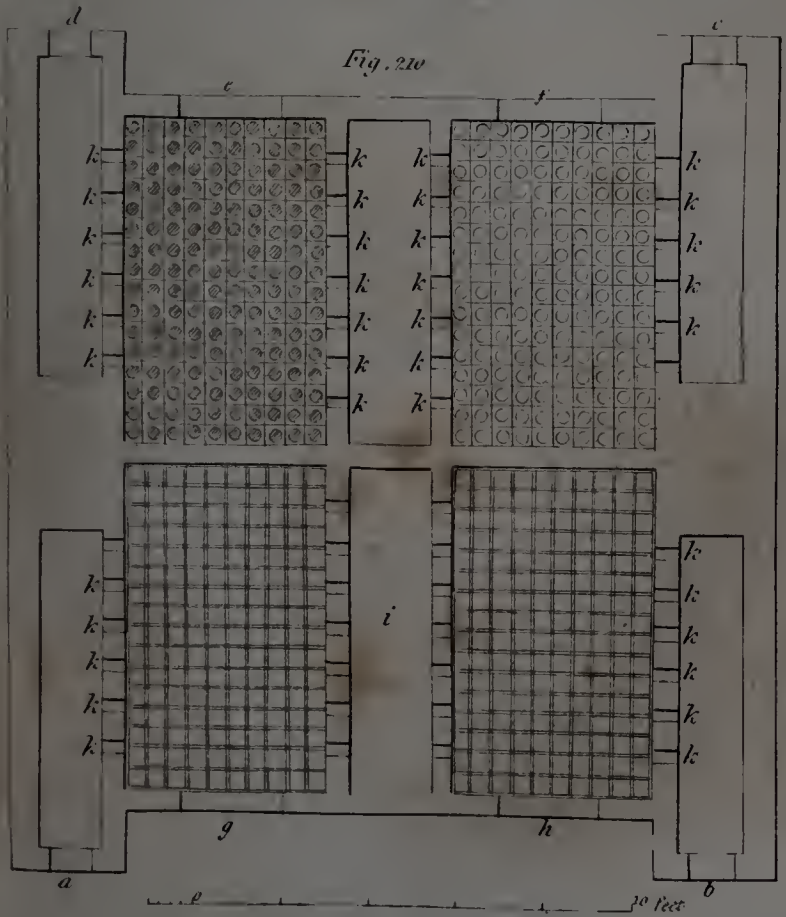



Fig. 210



The annual production of zinc from the mines in Carinthia, 3000 cwt.

The same kind of furnaces are used in Poland and Silesia; but as the fuel employed there is pit coal, some slight alterations are made in their construction. In Silesia, the pots are two feet wide in their upper parts, which is, in fact, their bottom.

At Liege, calamine is distilled for zinc in another manner. Earthen pipes are placed horizontally across the furnace, and open at both ends. They are charged at their widest end, which is afterwards stopped with clay, with a mixture of 100 pounds of stamped and roasted calamine, 15 of ground charcoal, and five each of common salt and argol. An iron pipe, slightly bent downwards, is luted to the narrow end of the distilling pipes, and is kept constantly cool by wet rags, to condense the vapours; and thus the zinc is made to fall in drops into water. The furnace is heated with coal, and as the distilling vessels cease to yield the metal, the wide end is opened, the charge withdrawn, and a fresh charge introduced, without withdrawing, or even diminishing the fire.

### *White Vitriol.*

This is obtained, as a secondary product, in the metallurgic treatment of the lead ore of Rammelsberg, near Goslar, which contains calamine mixed with it.

When the ore is roasted, it is thrown, while yet hot, into large troughs filled with water; which is afterwards drawn off, evaporated in leaden boilers, and let off into wooden cisterns, where it remains several weeks. The crystals thus obtained are melted in a copper; the milky liquor into which they are resolved is scummed, ladled out into square wooden boxes, and stirred with a wooden spatula till it is quite cold. After some time it becomes solid, but of a loose and spongy texture, like loaf sugar.

If the water from the ore troughs is judged to contain a notable quantity of iron and copper, some zinc is added in the boiling, to separate these metals.

White vitriol is principally used in oil painting, to cause the oil to dry quickly.

According to Dr. T. Thomson, its composition is $Zn \cdot S: \cdot + 3\,H \cdot$, and its atomic weight, 13,625.

### *Sulphate of Zinc.*

This is manufactured by dissolving zinc in oil of vitriol, weakened by the addition of six or eight times as much water, evaporating the solution to a pellicle, and setting it by to crystallize.

The crystals dissolved in water, is a common wash for sore or weak eyes; but they are useless as a dryer to oil paint.

Berzelius calls it *sulphas zincicus cum aquâ*, or Zn: S:· 2 + 10 Aq. and atomic weight, 3,133,120. Dr. T. Thomson makes it Zn· S:· + 7 Aq. and weight, 18,125.

### *Zinc White, or Carbonate of Zinc,*

Is manufactured by pouring into a solution of zinc, in sulphuric acid, a so tion of carbonate of ammonia, as long as any sediment falls, which is to washed and dried.

It is used for a paint, but does not cover so well as white lead.

### BISMUTH, OR TIN GLASS.

Bismuth, as it is called in chemical books, is usually know by the name of tin glass among workmen; evidently a co ruption of the common French name, *etain de glace*, tin f silvering glass; as the name, bismuth, is of the weiss mut or white mother of silver, of the German miners.

When pure, no metal is so easily obtained in the form crystals, which are small cubes grouped together. The b muth is to be melted in a covered crucible, and a good he given to get rid of any arsenic it may contain. It is then be poured out into a warmed black melting pot, having a hole its side closely stopped with a wooden peg. As soon as bismuth has set at top, the peg is to be withdrawn, that the quid part of the metal may run out. On turning out the so crust of metal, it will generally be found finely crystallized its under surface.

Bismuth, like cast iron, expands as it sets, and even retai this property when mixed with other metals; hence it is used the letter founders in their best type metal, to obtain a sha and clear face to their letters.

### *Extraction of Bismuth from its Ores.*

Bismuth is a metal very easily melted, and the only or smelted want merely the application of heat to run the me from the stone in which it is enveloped. Hence bismuth sometimes obtained by merely lighting a wood fire upon hearth of rammed clay, and throwing the ore into the fi When the fire goes out, the bismuth is separated from the ash by washing them in water, remelted in an iron pot, and pour into ingot moulds.

Bismuth is also obtained by the same apparatus of doub pots, as crude antimony.

The greatest part of bismuth used in Europe, is obtained Schneeberg, in Saxony, by the following apparatus:—Fi pipes of cast iron, five feet long, and eight inches wide, a placed side by side, and with a very gentle slope, in the upp part of a fire room, which is covered with an arch, having

ew vent holes, serving as chimneys. The whole furnace is 3 feet long, 6 feet high, and 4 feet 7½ wide, so that the ends f the pipes stick out about three inches on each side. One f these ends used for charging, is closed when necessary, with n iron cover; the other end is stopped up constantly with an arthenware stopple, having a notch in it to allow the metal as t melts to run out. A cast-iron pot, set on a chafing dish, is laced under this end of each pipe to receive the bismuth as it ows, and keep it melted under a covering of charcoal dust. Tubs of water are placed under the other end of the pipes, nto which the charge when drawn out of the pipes is hrown.

The fire being lighted, and continued for three or four hours, bout half a cwt. of ore, broken into pieces the size of a nut, s charged into each. In about 10 minutes the metal begins to un out at the other, and this continues for half an hour. The charge is then withdrawn, and a new charge introduced. When the iron receiving pots are nearly full, the metal is laded out into other pots, where the charcoal dust is scummed off its urface, and it is left to cool; thus forming cakes of from 25 o 50 pounds.

Twenty cwt. of the ore at Schneeberg, yields in eight hours bout 1½ cwt. of bismuth, and there are consumed about 63 ubic feet of wood.

Bismuth is also obtained in the same manner from the speiss f the smalt works, when the cobalt ores used in them are mixed with bismuth.

### *Fusible Metal, or Metallic Pencils.*

When bismuth is added to a mixture of lead and tin, it causes them to melt with a very low degree of heat. Equal quantities of these three metals may be melted in a bit of paper over a candle, without burning it; but the mixture that melts with the smallest heat, is that of 8 oz. of bismuth, 5 oz. of lead, and 3 oz. of tin, which melts at 202 deg. Fahrenheit. Hence toy spoons are made of them, which being given to children to stir very hot tea, melt while they are using them. Parkes has proposed the use of these compounds of lead and tin, with or without bismuth, in certain proportions, to form metallic baths, in which cutlery may be immersed for the purpose of tempering it always at the same precise temperature.

Another use of this fusible alloy, as it is called, is for making metallic pencils to write upon paper, prepared by having burnt hartshorn well rubbed upon it. The marks are as fine as those of black lead pencil, and not so easily rubbed out. Memorandum books of this kind are very convenient, being equally

ready for use with black lead pencils, and yet as permanen as ink.

### REGULUS OF ANTIMONY, OR REGULUS.

This is more usually called by the simple name of *regulu* only, among artisans.

The manufactory of regulus of antimony, on a large scale is carried on at Riom and Clermont, in Auvergne. The sul phuret of antimony, called common antimony, is first roaste in a reverberatory furnace until it forms a gray oxide; a cwt of this is afterwards mixed with 8 or 10 pounds of argol, an the mixture smelted in large melting pots placed in a wind fur nace. As regulus of antimony is very fusible, the furnace re quires no chimney.

Lampadius proposes to smelt the gray oxide thus obtained nearly in the same manner as lead is smelted from litharge. Bu instead of bellows, he introduces the air by three openings to wards the bottom of the furnace; and procures a sufficient hea by adding a chimney at the top of the furnace; thus changin it into a wind furnace.

About 1788, the manufactory was attempted at Glendinning in Scotland, by smelting the antimony with a proportion o iron to abstract the iron, as in making the martial regulus o antimony of the apothecaries. The same process was also adopted at Vienne, in France; but both of these manufactorie have been stopped; partly on account of the small demand fo this metal.

Regulus is added in making a few compound metals, to give hardness to the mixture; as in the best pewter, in some type metal, and in casting leaden medallions.

### *Common Antimony.*

Common antimony, called by theorists sulphuret of antimony, is obtained from the ore of the same nature by merely running it free from the stony matrix. As it is very easily melted, it is only necessary to put the ore into a crucible or other pot, having holes bored in its bottom, to insert this pot in the mouth of another, and apply heat to the upper pot to melt the ore, and thus cause it to run into the lower pot, which is kept cool.

Formerly, a number of the lower pots were sunk in the ground, and the upper pots being luted to them, a covered heap of wood placed upon the whole, was set on fire, and when the wood was burned out the pots were removed, and the crude antimony found in the lower pots taken out for sale;

hile the matrix which is much less fusible remained in the pper pots.

As a great part of the heat is wasted in this disposition of e pots, unless charcoal be made at the same time, a furnace s been used to heat the pots.

Fig. 211, represents the plan of this furnace, as built at Anglebas, in Puy Dôme; and fig. 212 its vertical section, in the direction, *t*, *u*, in the plan. is the opening into the fire room, *b*, and is closed by an iron door. *B*, is grate, which is moveable, and is also the space in which the workman nds while he ranges the pots on the bank. *C*, *d*, *e*, is a bank of brick rk surrounding the fire, so that the entire diameter of the internal part of furnace is about 10 feet; this bank is bound together by two strong iron ops. *F*, *g*, *h*, *i*, are small flues in the sides and crown of the furnace, conecting the burned air and smoke into *k*, the chimney of the furnace, which very short. This chimney is, however, topped by another, about 17 feet gh, built of bricks, upon a strong plate of iron, supported at each of the ur corners by an iron bar, attached to the roof of the shed; by turning the uts of the screws, this moveable chimney is adjusted to the chimney of the rnace, and the joint closed with clay.

This furnace holds 75 sets of pots. The upper pots are 19 ches high, 11 inches wide at top, and 8 at bottom, in which ey have five holes, about ½ inch in diameter; these pots are arged with 40 pounds of ore, ⅓ rich ore placed at bottom, ore mixed with the matrix in the middle, and ⅓ poor ore aced at top. The lower, or receiving pots, are the middle ctions of a sphere, 10 inches in diameter, cut off at top and ttom so as to stand 9 inches high; and the mouth at bottom be 8 inches wide. The placing of the pots takes three men hree hours' labour.

The firing, which is given by beech wood, is weak for the rst hour, then gradually increased for three hours, when some gots of broom, are thrown in, to give a sudden and flaming re, which is gradually slacked for two hours. This firing onsumes about 15 or 16 cubic feet of beech wood, and 20 room fagots. The operation, including the cooling of the rnace, takes up a day, or a day and a half; and 300 cwt. of re produce about 15 cwt. of smelted antimony. One half of he pots are usually broken.

To save this expense of pots, it has been proposed to run he ore in iron pipes, lined with clay, and placed across the rnace, as in smelting bismuth ore. It has also been attempted to smelt the ore on the bed of a reverberatory furnace, the ed being made of clay, with a slope towards the eye, which vas left open so that the smelted metal might run out as soon s it was rendered fluid, and be received in pots for sale. But neither of these methods have prevailed.

Common antimony is used to make the regulus and glass of antimony. According to Berzelius, who calls it *sulphuretum stibii*, it is $Sb\,S^3$; its atomic

weight is 2,216,380, and it contains 7277 parts of regulus in 10,000. Dr. Thomson makes it Sb S, and its atomic weight 7500.

### *Glass of Antimony.*

This is manufactured by grinding common antimony to po der, calcining it in a very gentle heat, till it becomes a lig gray oxide, and does not emit fumes in a red heat. If a clots are formed by the heat being too great, they must taken out, ground down, and again returned to the furnace.

The oxide thus obtained, is to be put into a crucible, a melted in a brisk fire, without any addition; it generally for a brown transparent glass. If the antimony has been calcin too much, it is rather hard to melt: some chemists in this cas throw a little common antimony into the crucible; but this a dition gives the glass a darker colour than if pure.

It is used to prepare tartar emetic.

Some years ago a druggist, being distressed and in the King's Bench Priso made a quantity of glass of lead, coloured it to imitate glass of antimony, a sold it for that article before the fraud was discovered. Some of this glass s remains in the apothecaries' shops, to whom it was sold.

Glass of antimony varies in its ingredients, according to the quantity of lica that it extracts from the crucible.

### *Crocus Metallorum.*

This is made by calcining common antimony until it acquires only a dull g colour, and then melting it in a crucible.

It is used to make emetic tartar.

### *Emetic Tartar.*

The old process for making this double salt, was to mix o pound of crocus metallorum with a pound of cream of tarta boil the mixed powder in a gallon of water for an hour or tw filter, evaporate to a pellicle, and set it by to crystallize; t mother water is again evaporated, until it ceases to yield cry tals.

But since glass of antimony has been manufactured on a lar scale, and thus may be bought cheaper than the crocus can made, it has been used in preference.

A number of other processes, some of them very complicate have been given for making this salt; but their use has bee confined to their inventors, as all the wholesale makers of em tic tartar use one or other of the above methods.

Emetic tartar is at present the most generally used antimonial medicine, a its exhibition may be managed so as to produce either sweating, purging, vomiting.

Berzelius calls this salt *tartras kalico stibicus*, or 3 K: T$-^2$ Aq$^2$+4 Sb: T Aq$^3$, and thus makes its atomic weight 28,235,830. Dr. T. Thomson thin it should be called *ditartrate of potash and antimony*, considers its composition

T−Sb·+T−K· Sb·2+2 Aq. and its weight, 44,250. Gay Lussac thinks the eam of tartar performs in this and similar salts, the part of a simple acid.

## *Kermes Mineral.*

The best process for making this medical article, much used y the Continental physicians, is to boil one pound of common ntimony, 22 pounds ½ of sub carbonate of potasse, and 20 gal- ons of water in an iron pot, filtering the liquor while hot into arthen pans, and letting it cool slowly for 24 hours; the Kermes mineral is deposited in form of a deep purple brown elvetty powder.

The supernatant liquor, on the addition of any acid, yields n orange sediment called *golden sulphur of antimony;* which he calico printers use as a yellow colour. The supernatant quor is evaporated and crystallized, the crystals dissolved in vater, the solution thickened with paste or gum, and thus rinted; the cloth is then dried, and passed through a very veak acid liquor, which separates the golden sulphur, and fixes t on the cloth. [For a more economical and particular account f the sulphuret of antimony with soda, or the orange crys- als, of the calico printer, see the sequel to the articles on the nanufacture of bleaching liquor in this work.]

### REGULUS OF COBALT.

Called by the theoretical chemists simply, *cobalt*, which is properly the name of the ore from which this metal is ex- tracted.

Regulus of cobalt is not smelted, but the ores are treated for the oxide of that metal, which is a rich blue colour.

## *Zaffre.*

Zaffre is prepared from the ores of cobalt that contain sul- phur and arsenic, and which are roasted 3 or 5 cwt. at a time, in a reverberatory furnace, with chambers attached to receive the arsenic. The ore generally loses rather more than one- third of its weight, so that a cwt. yields about 68 pounds of zaffre, or zafflor.

The ores that contain much nickel are not fit for the pre- paration of zaffre, as the oxide of nickel would injure the beau- ty of the blue colour, or smalts; for the making of which, zaffre is manufactured.

Inferior kinds of zaffre are made by mixing this oxide, pre- viously stamped and sifted to a fine powder, along with cal- cined flints, or quartz, also ground in various proportions, ac- cording to the use for which it is intended, moistening the

whole with water, and packing it tight in casks, where it hardens to a stone.

A very fine zaffre, or China blue, is obtained from the arsenical and gray cobalt ore, found in Cornwall, by boiling the powdered ore in nitric acid, which converts the arsenic into arsenical acid, and unites it with the different metals contained in the ore. The solution being diluted with a large quantity of water, purified pearl-ash water is then added in small portions to the diluted solution, and on the addition of each portion the liquid is well stirred, left to settle, and the clear poured off. This is repeated until the solution becomes of a rose colour, which shows that it contains only the arseniate of cobalt. The pearl-ash water is then added in larger quantity than is necessary to throw down all it contains, and the solution is boiled for a few minutes. Being then left to settle, the liquid is filtered, the oxide of cobalt left on the filter washed with boiling water, and dried. This oxide is then melted with fel spar and a little potash, and thus yields a beautiful zaffre for painting China ware.

Another method is to grind the ore, mix it with two or three times its weight of China ware grossly powdered, and heat very strongly. The whole is then put into three or four parts of nitric acid, diluted with an equal weight of water. The clear solution is poured off, evaporated gently to a syrupy consistence, diluted afresh with water, left to settle, poured off clear from the arsenic that is separated, and then the pearl-ash water is added by small portions, and the operation finished as in the former process.

Zaffre is used for making smalts, and for painting on the best kinds of pottery. The common zaffre is very cheap, but the best kind sells in the potteries for two guineas by the pound. It is also used to make cobalt.

### *Smalt, or Powder Blue.*

Smalt is a glass, coloured with oxide of cobalt.

The natural oxides of cobalt are merely stamped, and very carefully washed. The other ores of cobalt are roasted and made into zaffre.

The basis of the glass is quartz, several cwt. of which are made into a heap with wood, and burned for 24 or 36 hours. It is then stamped in water, calcined in a reverberatory furnace, and sifted. The potash is carefully prepared, calcined, and kept dry.

A number of assays are made with these ingredients, to which are sometimes added white arsenic, black arsenic, and

he glass obtained by a preceding operation. The blue glass esulting from these assays, is ground, washed, and the colour ompared with that of specimens kept as standards of the pro- er quality.

The furnace used is similar to that for making flint glass; in ome places it is square, in others round. It generally contains ight pots, nearly cylindrical, two feet high, and as many wide. n Hesse, the pots have an opening on the side even with the ottom, and there is, besides, the usual working hole—another n the walls of the furnace, to allow the workman to close or nstop this hole in the pot. When the melting pots are new, hey are spread over on the inside with powdered blue glass, efore they are charged, in order to varnish them.

In general, for the best smalt, two parts of oxide of cobalt re melted with one of powdered quartz; and for the inferior malt, with three parts of quartz. The calcined potash is used n nearly the same quantity as the quartz, and there is added ne-sixth or one-eighth of the glass obtained in a former ope- ation.

The furnace being heated, a cwt. of materials is charged by a eel into each pot, and this charge is usually melted in eight ours; for the last three hours it is stirred several times. When the glass sticks to the rod, and can be drawn into threads, the hole in the bottom of the pot is opened, and the speiss, or metallic matter that has settled at the bottom, is let to run out. After which, the glass itself is ladled out of the pots, and flung into a trough having a current of cold water running through it. In some manufactories, the speiss is not run off; but when rather more than half the glass has been la- dled out, the workman lets any speiss he may take up in the la- dle settle, and drops it into an iron basin.

When the pots are thus emptied, they are charged afresh, and thus 24 cwt. of materials are usually melted in the course of 24 hours, and there are consumed about 2016 cubic feet of very dry resinous wood. The produce is generally 19 cwt. of blue glass, and ½ cwt. of speiss. The furnace is generally kept in continual use for 18 or 20 weeks.

When the speiss is rich in cobalt, it is used again. For this purpose, if it contains much bismuth, this is sweated out of it by the usual process for smelting bismuth; and then the speiss is stamped, screened, roasted, in a reverberatory furnace; again screened, and used as the other oxides of cobalt.

The blue glass thus obtained is first stamped, then sifted, and ground with water, 2 or 3 cwt. at a time, between granite stones. After some hours' grinding, the water and ground smalt is let to run into large tubs, where in a few minutes that part

of the powdered glass which is the best coloured, by bei richest in oxide of cobalt, settles, and is sold under the nam of *strewing smalt*. The other part is ground over again wit water, and run into other tubs, where it is allowed to settle f about an hour; the glass that settles in these tubs, are sold by th name of *farbe*, or colour. The water is run off into other tub where it stands until quite clear; the smalt collected in these called *eschel*, or ashes.

All of these sediments are washed over again, sorted int various qualities, and dried on slabs, either in a stove, or i sheds, with a free current of air. The cakes thus produce are crushed, either between cylinders, or by rakes, turned b water, or by ordinary mill stones; or lastly, between tw planks moved contrary ways. After which, they are sifte or bolted. 100 cwt. of blue glass yields about 60 cwt. of co lour, or 70 cwt. of ashes.

The strewing smalt is used in painting, and the others i tinging linen and paper of a blueish colour.

### *Speiss.*

Speiss is a secondary product obtained in making smalt, s parating from the glass during its fusion, and settling at th bottom of the pots.

It is a mixture of cobalt, nickel, iron, arsenic, bismuth, t which is sometimes added silver.

When it is rich in cobalt, it is used over again in the makin of zaffre: and when rich in bismuth, it is used to obtain th metal.

Speiss is also the material from whence the experimento chemists generally obtain nickel.

## PLATINUM.

This metal, which in the state it is usually obtained, alloye with palladium and rhodium, joins the hardness of iron to th resistance of most chemical agents possessed by gold, is lately come into much use.

It is obtained from the ore brought from Spanish America by the name of platina, the diminutive of plata, silver; and which is a kind of metallic sand. The platina is dissolved by the help of heat, in eight times its weight of a mixture of two parts of muriatic acid, at 22 deg. Baumé, and one of nitric acid, at 34 deg. Baumé. When the acid ceases to act, it is to be decanted, and fresh acid poured on the residuum, until all i taken up that the acid will dissolve, which generally require

our parcels of the acid. By this means, the iridium and osmium in platina is left in the residuum.

The acid solution is then evaporated until it crystallizes upon boling, in order to drive off the excess of acid, and diluted with 10 times its weight of water. A solution of sal ammoniac, made as strong as possible, is poured into the solution of the platina, in a quantity beyond that necessary to throw down, all the sediment it will yield. This sediment, which is an ammonia-muriate of platinum, is thrown upon a filter and well washed.

Platinum may be obtained directly from this ammonia muriate, by putting it into a crucible, and exposing it to the utmost degree of heat the chemist can command, observing to press down the mass with a button-headed iron rod, as the salt assumes the metallic form. When completely reduced, the regulus must be taken out of the crucible, and carefully forged; returning it frequently into the fire.

Another method, is to reduce the ammonia muriate by heat alone, without compression, and to melt the spongy mass of platinum alloyed with palladium and osmium thus obtained, with one-eighth its weight of black arsenic, and casting it to thin plates, or small rods. This compound metal is then repeatedly heated and forged, until the arsenic is driven away.

Willis found, that platina might sometimes be melted upon a bed of charcoal in a crucible; and M. Boussingault has lately found that platinum always melts in a blast furnace, if the crucible is lined inside with a mixture of clay and charcoal. He thinks this fusion is owing to the admixture thus produced, of silicon with the platinum.

Platinum may be melted in small quantities not exceeding two ounces, by the blast of the oxy-hydrogen blow-pipe, and even kept in fusion for some time.

Platinum is used for crucibles, evaporating dishes, and even alembics: it resists most of the acids, but is acted upon by caustic potasse, and several neutral salts. It may be welded like iron, and the proper solder for it is gold.

The solution of platina is used as a test to distinguish water containing potasse from that containing soda.

The concentration of oil of vitriol is now generally performed in platina stills, with leaden heads. Mr. Parkes had a still of this kind which held 35 gallons, and cost 300 guineas.

### BLACK ARSENIC.

Black arsenic is the proper commercial name of the metal simply called *arsenic*, by theorists, and is manufactured by

distilling powdery white arsenic along with a little charco dust, and some iron filings and lime, so that if any sulphur contained in the white arsenic, it may be hindered from risin Arsenical pyrites, ground fine, is also used, and seems pref rable.

The apparatus is the same as for red arsenic; only a sheet iron, rolled up like a cylinder, is used as an adapter. Whe the apparatus is cooled, this iron adapter is unluted, and bein unrolled, the black arsenic is found sublimed upon it in brilliar crystals, which soon grow black in the air.

In the neck of the receivers there is found a mass compose of black arsenic and white arsenic, which is sometimes sold b the name of flie gen stein, *fly stone;* but is more generally use in the next process, along with the powdery black arseni found in the receivers.

### *White Arsenic.*

White arsenic, in a powdery form, is obtained as a seconda ry product in the chambers attached to the furnaces used fo smelting lead and tin ores, and in several other metallur gical processes. Arsenical pyrites are also roasted expres ly for the purpose in reverberatory furnaces, with chambers a tached.

As white arsenic is in this form very dangerous for carriage on account of its poisonous quality, it is reduced to a glass form by sublimation in large iron matrasses, formed of severa pieces luted together.

Two of these matrasses are usually heated over one fire The furnace is about 12 feet long, 6 wide, and 4 high the two cast-iron pots which are set in this furnace, and serve as the bottom of the matrass, are two feet wide, and as many deep, hanging loose in the furnace by a flange round their mouth. Each of these iron pots are charged with 3 cwt. ½ of powdery white arsenic, and then covered with a head made either of cast or hammered iron. These heads are cylindrical, four feet high, as wide as the pots, and contracted at top into a cone, a foot high, to which is adjusted a long pipe of sheet iron, a few inches wide, and ending in a chamber built over the furnace, and having a chimney at one end.

The joints between the pot and the head being luted with clay, mixed with blood and hair, the fire lighted and kept up for 12 hours, after which the apparatus is left till the morrow to cool, when the head being taken off, the glassy white arsenic sublimed in it is knocked off and sorted; the whitest parts are packed in barrels for sale, and the impure parts, as well as

at left in the pot, reserved for another sublimation. Each t produces about 3 cwt. of glassy white arsenic, and the ating of the two pots consumes about 90 pounds of pit al.

In some workshops, the heads put over the pots are open at p, the pots are not charged, but when they are red hot, a few unds of powdery white arsenic are flung in at the top of the ad, the opening of which is then closed with a tile; and this repeated at short intervals. This method exposes the work- en too much to the noxious vapours.

If the powdery white arsenic contains any sulphur, a little tash is mixed with it, to hinder the sulphur from rising.

### *Red Arsenic, or Realgar.*

Red arsenic, or realgar, is manufactured by distilling a mix- re of arsenical pyrites with iron pyrites, or of powdery white senic with rough brimstone.

The distillation is performed in earthen retorts, coated with mixture of clay, iron filings, blood, hair, and alum. These torts are filled about two-thirds, ranged in a galley furnace, d an earthen receiver is luted to each. The receivers are erced with a few small holes, to prevent an explosion. The ing lasts eight hours, and when the apparatus is cooled, the d arsenic, mixed generally with some yellow arsenic, is taken t of the receivers; the yellow part is added to the mixture ed in the next operation.

The red arsenic thus obtained, is melted over again, under chimney that has a quick draught, to carry off the vapours. is melted in a cast iron pot, set in brickwork; when melted is scummed, and ladled quickly into sheet iron moulds, which e immediately covered and left to cool.

The mixture of the charge must be properly proportioned, that there may be from 3½ parts to 5 parts of white arsenic, one of sulphur.

The residue left in the retorts is stored up, and used in aking copperas.

### *Yellow Arsenic, or Orpiment.*

Yellow arsenic, or orpiment, is manufactured by mixing ar- nical pyrites that have been exposed a long time to the air, ith one-tenth their weight of iron pyrites, and distilling the ixture in earthen retorts, as described in the article—Red Ar- nic.

Lampedius says yellow arsenic is composed of from 7½ to 9 arts of white arsenic, united with one of sulphur.

Yellow arsenic is also, and more commonly, prepared in t same apparatus as glassy white arsenic, by adding to the 3½ c of powdery white arsenic, that forms the charge of each pot cwt. of rough brimstone, if the powdery white arsenic is pu or only 9 pounds of pure sulphur, if the powdery white arse already contains sulphur.

### *Macquer's Neutral Arsenical Salt.*

This is manufactured on a large scale, by mixing white arse with an equal weight of refined saltpetre, heating it in a cru ble until the whole is red hot, dissolving the mass in wat evaporating and crystallizing the solution.

The neutral arsenical salt is used in dyeing; and also in medicine.

This salt is the *bi arsenias kalicus* of Berzelius, or K· As:·:², and its aton weight is 4,061,370. Dr. T. Thomson calls it *bi arseniate of potasse*, or As:·² + Aq. and its weight, 22,625.

## CHROME.

This grayish white, brittle, and scarcely fusible metal, is not used; but t combinations of its oxide, or as some call it, its acid, with other bodies, are u as colours; and from this circumstance, the Greek name of chrome, *colour*, been given to the metal itself.

Chrome is not found pure in nature, but all the combinations are made f an ore, in which its oxide is combined with that of iron, and hence called c mate of iron.

### *Chromates of Potasse.*

The ore called chromate of iron being carefully picked, stamped fine, and being mixed with half, or an equal weight refined saltpetre, is put into skittle crucibles, so as to fill the about three-fourths of their height. The crucibles are then p into a furnace, gradually heated, and at last kept red hot f half an hour. Being cooled, the crucibles are broken, the ye low spongy mass ground to powder, put along with the shar into a copper, along with 10 times its weight of water, an boiled for about half an hour. When cold, the liquor is filtere and fresh water boiled upon the residuum, until it no longer a quires a yellow colour.

The several parcels of water being mixed together, are to b evaporated to reduce them to a less compass, and saturated wit nitric acid to get rid of the silicate of potasse and aluminate potasse which they contain. The water is then filtered to s parate the two earths, and potasse is added until it again b comes yellow. By a careful evaporation and cooling, the n trate of potasse crystallizes, and scarcely any of the chromat of potasse which is retained in the supernatant liquor.

This mother water being evaporated, deposites, upon cooling very beautiful orange red crystals of the acid, or bi chromate potasse; and the supernatant liquor being again evaporated

ields a second crop of these crystals. The mother water is w very alkaline, and yields on further evaporation, yellow ystals of neutral or sub chromate of potasse.

Chromate of potasse is used for making chromate of lead ; and also in calico nting.

The bi chromate of potasse, according to Dr. T. Thomson, is Ch:·2 K·, or 1000 ; and the sub chromate Ch:· K·, or 12,500.

The following process for the manufacture of the chromate and bi chromate potash is that of an English manufacturer of considerable celebrity, and differs considerably from the foregoing.—Take 100 lbs. of the best American chromate of iron in fine powder, and mix well with 60 lbs. of nitre in powder and ; divide this mixture into parcels of about two pounds each, and wrap them in paper in the form of cones of the same height as the diameter of the base, in the manner in which grocers frequently do up a pound of brown sugar; cover the grate of a furnace, whose height shall be twice that of its length on the side and of a size to correspond with the extent of the manufacture, with a stratum of fragments of charcoal; then put in as many cones with the bases downwards as will cover the stratum of coal; fill the interstices with charcoal, and cover the cones about two inches deep;—lay in another stratum of cones, and so on, until the furnace is filled to within two inches of the top. Throw some burning coals upon the top, and place on the iron cover, which should have a flue of sufficient height to cause a moderate draft. The fire will burn slowly downwards till all the charcoal is consumed. Allow the furnace to cool; then take out the cones, which will preserve their shape, and dissolve out the chromate of potash with a sufficient quantity of water;—saturate the excess of alkali in the solution with nitric acid, and, if the bi chromate be required, add an excess of acid;—evaporate and crystallize the clear solution.

### *Sulpho Chromate of Potasse,*

is apparently made by mixing the solution of sulphate of potasse, and that of chromate of potasse ; a triple salt is formed, by crystallizing the liquid.

Dr. T. Thomson, who obtained this salt, by mixing the solutions in the proportions of 3 atoms, or 37½ parts of chromate of potasse, and 1 atom, or 11 parts of sulphate of potasse, says the crystals he obtained were composed of 6 atoms, or 66 parts of sulphate of potasse, and 1 atom, or 12½ parts of chromate. 100 parts of the crystals sold in France to the calico printers, are said to contain only about 40 of sulphate of potasse.

### *Potasse Chromate of Alumine.*

This is also manufactured in Germany.

### *Chrome Yellow.*

This beautiful colour is obtained by dissolving sugar of lead in a very large quantity of water, and pouring into it the rough solution of chromate of potasse, from which the nitrate of potasse has been just separated by crystallization, as long as any sediment falls. The liquor is then filtered, and the yellow left on the filters, dried for sale.

Chrome yellow is used as a paint : and it is frequently sold for *peoree*, or *Indian yellow*, which is a gall stone.

This is the *chromas plumbicus* of Berzelius, or Ch::: Pb:, and its atomic weight, 1992,640. Dr. T. Thomson makes this chromate of lead Ch:· Pb·, or 20,500.

There is a cheaper chrome yellow manufactured, of a bright anquil tint, which probably is lowered with alumine.

### *Chrome Scarlet.*

There are several processes for preparing this beautiful colo
Dulong's is to boil 67 parts of white lead, and 82 parts chrome yellow, in a sufficient quantity of water. The carbo acid of the white lead flies off, and the oxide of lead unites w the chrome yellow.

Grouvelle's method is, to boil 41 parts of chrome yell and 11 parts of subcarbonate of potasse, in a sufficient quant of water; the carbonic acid flies off, as before, and the pota uniting with one half of the chromic acid, leaves the other h with a double portion of oxide of lead.

Chrome scarlet is a good oil colour, possessing a good body, and mixing w with white lead; as a water colour, it has stood for several months in expo situations, and is equal in colour to red lead.

This sub chromate of lead is, according to Dr. T. Thomson's atomic weig $Ch^{\cdot} Pb \cdot ^{2}$, equal to 34,500.

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Besides the metals hitherto mentioned, there are seve others which have not yet been used in the arts; and are o made to be exhibited by theoretical lecturers to their audito as palladium, nickel, cadmium, manganese or manganium, lurium, molybdenum, tungsten or wolframium, columbium tantalum, selenium, osmium, rhodium, iridium, uranium, tit um, cerum; as also the doubtful metals—calcium, barium, str tium, magnesium, yttrium, glucinum, aluminum; and the more doubtful—selenium, potassium, sodium, lithium, silic and iodium.

## COMBUSTIBLES.

This last class of the subjects of chemistry, is far more n merous than any of the others; but a great part of it is mer natural products, and of course the object of natural histo not of chemistry; another great part is composed of artic made indeed by chemical means, but only in small quanti for medical purposes, to illustrate points of theory, or in analysis of natural bodies. The operative chemist confines attention to those substances which are made in large quanti for sale or use.

### INFLAMMABLE GASES.

The manufacturing of any gas of this kind was formerly c fined to that of hydrogen gas, for filling the balloons used aërial navigation; but of late, the manufacture of inflamma gas for lighting our houses and streets, has been carried t very great extent, and become of considerable importance.

## *Hydrogen Gas.*

This gas, the *light inflammable gas* of Dr. Priestley, has been chiefly collected ing the solution of iron turnings in weak sulphuric acid, made by adding to of vitriol about six times its weight of water. An ounce of iron, according Mr. Cavendish, produces gas equal in measure to 412 ounces of water; but the solution is of no value, it is preferable to employ zinc, although an ounce es not produce more gas than is equal in measure to 356 ounces of water, or ubic feet ·7 of gas from each, avoird. pound; because the solution being led down and crystallized, will yield sulphate of zinc, which is more valua- ; 50 pounds of oil of vitriol will dissolve 36 of iron, or 34 of zinc.

A cubic foot of pure hydrogen gas weighs about 40 grains, and of atmosphe- air, about 527; but as the hydrogen gas is not absolutely pure, the buoyancy each cubic foot of gas in the atmosphere cannot be estimated at more than avoirdupois ounce, from whence the weight of the varnished cloth, cords, ves, and car, must be deducted.

## *Coal Gas.*

This is become the most valuable product of the distillation coals; and its use is now so extended, that numerous estab- hments for its production are formed throughout Europe, and en America. The apparatus varies in almost every gas work, t is in general constructed on the following principles:—

The distilling vessels are usually modifications of those direct- by Boerhaave to be used in his reverberatory furnace. The lindrical retorts which are most commonly used, are 6 feet ng, and 12 inches in diameter, with the mouth closed by an on plate, fastened by wedges holding 2 bushels, or 168 pounds coals, and these, when set two to one fire, and worked so as distil off all the gas in eight hours, require about 20 bushels coals to distil 100 bushels. These retorts, cast from iron of e second running, weigh about 10 cwt. and last from 8 to 10 onths.

In some works, the section of the retort is not circular, but liptical, semi-circular, lunulate, or square; and they are set 3, or even 5, to one fire. The setting is also various, for some rnaces have flues round the retorts—in others, an oven or amber to contain all the retorts, is built over the fire room, fire rooms, for some of these ovens have three fires to heat em, and contain even as far as 12 retorts. The fire room is metimes placed towards the front of the retorts, but more ge- rally at their back. In some works, the coals are introduced to the retorts in trays of sheet iron, holding only a small antity, and frequently changed. In others, very complicated achinery is used to expose a part of a circular box, divided to partitions, to the heat; and when this coal is decomposed, e box is turned round, and another partition exposed to the at. Attempts have also been made to form the furnace into coke oven; or to render applicable occasionally to making of ke from the fuel used in the distilling.

The vapours of the heated coal pass off from the retorts by means of a dip or H pipe, which is inserted on their upper side near the mouth, rises about 3 feet 9 inches, and then bends and descends about 2 feet 6 inches, passing through a hole in the upper side of the hydraulic main, and reaching about two-thirds of its diameter. These dip pipes are generally 3 inches in diameter.

The hydraulic main, or condenser, is a large cylindrical pipe from 10 to 14 inches diameter, supported in a horizontal position by iron pillars, parallel to the front of the top of the brick work of the stack of furnaces, about two feet from it, and extending along the whole range. It is generally constructed in lengths of nine feet each, with flanches to screw them together; between each length a semicircular plate is placed, whose upper edge rises $2\frac{1}{2}$ inches above the line of the bottom of the dip pipes, in order to retain a sufficiency of the liquid products, that the gas may always have to pass that depth of liquid before it can enter the main, and that when the mouth of any of the retorts are opened to discharge and recharge them there may be a sufficiency of liquid to pass up the dip pipe and operate by its pressure as a water joint to prevent the gas from the other retorts connected with the main, rushing out from the mouth of the opened retort. For which purpose the main is, at the commencement of the work, filled with water; and afterwards, the condensed products keep the partitions filled, running off at one end of the main along with the gas by a pipe for that purpose; the other end of the main being closed by a plate screwed on air tight.

The pipe, which carries off the tar and ammoniacal liquor along with the gas, from the hydraulic main, communicates with the condensing apparatus; as it is absolutely necessary that all the condensible products should be separated before the gas enters the purifiers. The condensing apparatus is in some a plain straight pipe of great length; in others, a range of pipes laid parallel to each other: both of these contrivances have a considerable declivity. In other works, a worm placed in the gasholder cistern, between it and the gasholder; and still more complicated contrivances have been invented.

As every chaldron, or 27 cwt. of coal yields from $1\frac{1}{4}$ cwt. to $1\frac{1}{2}$ of tar, and from 16 to 20 gallons of ammoniacal liquor, a tar cistern must be provided to collect it, and a communication is formed between the lowest part of the condensing apparatus and the tar cistern, by a pipe of about 3 inches diameter, which passes to near the bottom of the tar cistern, and is enclosed in another pipe, 2 or 3 inches wider, and reaching nearly to the top of the tar cistern; by which means, the gas

prevented from entering into the tar cistern, and the tar and quor flows over the brim of the outer pipe. The tar cistern generally made of cast-iron plates, or of masonry, sunk in e ground; is provided with floats, to show the height of each quid, and covered to prevent the ammoniacal liquor losing its rength. The liquids are extracted by means of pumps, or metimes, if the tar cistern is above the surface of the ground, y cocks placed at different heights.

The tar and ammoniacal liquor being thus collected, the uncondensed gas is passed into the purifiers, to separate the incombustible carbonic acid gas, and the fetid sulphuretted hydrogen gas, from the olefiant gas, hydrogen gas and carbonic xide, which seem to compose the remainder of the raw coal as. Two methods are employed for this purpose: the exposing of the gas to the action of lime, or the passing of it rough red hot pipes, filled with clippings of iron. The lime which the gas is exposed, is sometimes dissolved in water, r mixed up with it to the thickness of cream, or it is merely etted with water.

The lime apparatus, when that alkaline earth is dissolved in ater, or in the form of cream of lime, is very similar to that f Berthollet for preparing oxymuriatic acid, described in p. 81, and exhibited in fig. 105; but formed on a larger scale, nd of cast iron. There exists, however, a considerable difculty to get rid of the lime refuse, as it is very offensive, and f thrown into pits dug for that purpose soaks through the round and infects the adjacent ponds, and wells.

The dry lime purifiers, as they are called, are always in airs, that one may be discharged and recharged, while the ther is in action. To purify the gas required for 500 lights, hey are each of them about 5 feet square, and 2 or 3 feet eep, formed of cast iron, with 3 or 4 ribs cast internally to upport as many shelves of plate iron, at equal distances, perorated with holes about $\frac{3}{8}$ of an inch in diameter, and their entres $\frac{3}{4}$ of an inch distant. The gas enters by a pipe in the entre of the bottom; the top has a trough round it, about 6 nches wide and 10 deep, filled with water to receive the over and form a water joint to prevent the gas escaping that vay; the exit pipe is on the side near the top. To charge this urifier the cover is removed, the upper shelves taken out, the ower shelf is then covered evenly 3 or 4 inches deep, with iew slaked lime, so far wetted as not to adhere to the hands, nd a gallon of water poured on it. The other shelves are hen put in, one by one, and covered with lime; and finally, he cover being put on, and the gas admitted, it is forced to nake its way through the several layers of wet lime. The

lime when discharged, is thrown into a cistern, through whi the air that feeds the fire is made to pass, and thus the dis greeable odour of the saturated lime is destroyed, and th lime itself is rendered of considerable value as a manure, and h been sold at an advance of one-twentieth on its original price

A bushel of quicklime, or 2150 cubic inches, is required f the purification of 12,000 cubic feet of gas; by slaking, mo kinds of lime double their original bulk. The hundred (peck by which lime is usually sold, is about 27 cubic feet.

The purification, by clippings of iron, requires two retort which are generally heated by one fire, as they are worke only at a red heat just visible by day light. Each of these r torts are divided lengthwise down the middle, by the partitio cast along with them, and reaching nearly to the hinder end the mouths of each division of these retorts is closed by a s parate plate, secured as usual. The pipe conveying the g from the condensers into these purifiers, is like that of the dr lime purifiers, branched so that the gas may be introduced int either of them at pleasure, and shut off from the other. Th retort being charged with iron clippings in each division, t mouth secured, and the retort brought to the proper heat, th gas is let on, and passes of course into one of the divisions the retort; then passing behind the partition, it passes throug the other division, and is conveyed from thence by a pipe t the gasholder. A small cock, to which bladders may be a plied, is placed on the exit pipe between the purifying reto and gasholder, for the purpose of examining the purity of th gas, by infusion of archel, sugar of lead water, or diluted n tric solution of silver. When the purity of the gas decrease the other retort is charged, the gas let on to it, and the fir retort discharged and recharged.

The gasholder is on the same construction as Accum's, de scribed in p. 213, and exhibited in fig. 102, but on a larg scale, generally holding 15,000 or 20,000 cubic feet; or 30 t 40 feet diameter, and 18 or 23 feet high. They are now mad of sheet iron, weighing about two avoird. pounds, 11 ounce by the square foot; and are usually worked at two inches pre sure of water, the pressure being ascertained by a small pre sure gauge attached to the top of the gasholder. The equalit of pressure is secured by making the weight of each foot o the chain suspending the gasholder, equal to the weight o water displaced by the gasholder being sunk to that depth i the tank.

The gas is then conveyed by pipes to the places where it i wanted.

Retorts, whose vertical section is elliptical, are generall

ferred; five of them are capable, upon occasion, of distilg 45 bushels, or 33 cwt. of coals, every day, and produce ,000 cubic feet of gas; but their average daily mode of workg may be estimated at one chaldron, or 27 cwt. of coal, so to produce from 12,000 to 14,000 cubic feet of gas, and a ldron ½ of saleable coke. The labourers find it easier to rk these retorts, even when the four hours' process is folved, than the same number of cylindrical retorts at the eight urs' process; as their shape allows the coke to be raked out re rapidly, especially as it is not so compact.

An improvement has been attempted, by introducing water o the front of the retort: a bent iron pipe to form a hydrotic funnel, the steam of which will tend to separate the aly matter from the gas.

### *Oil Gas.*

The apparatus for procuring this gas, is similar to that for al gas, but constructed on a smaller scale; the following are e necessary variations:—

The retort, which is charged with pieces of hard brick, rewed from time to time as often as they lose the power of demposing the oil, has besides the dip pipe near its mouth, aner pipe, bent so as to form a hydrostatic funnel, and passg from an oil cistern placed above the furnace, to near the outh of the retort, and from thence within it, on the upper rt, to near the middle. This pipe is also furnished with a ck, by turning which, the charges of oil are made to flow to the retort.

The gas, in passing from the hydraulic main to the gasholds, passes through several vessels filled with oil, to condense y oil that may have been volatilized without decomposition; d as this gas does not contain any sulphuretted hydrogen, is is the only purification that it requires.

Oil gas is procured in England from whale oil.

A ton of good whale oil produces 25,000 cubic feet of gas. gallon of cod oil produces but 85 cubic feet ½ of gas.

As its illuminating power is rather greater than that of coal as, it is used for portable gas lamps. These lamps are much eaner in their use than oil lamps; but the experiments of Messrs. Herapath and Rootsey tend to show, that there is a ss of 28 parts in 100 of illuminating power, by converting il into gas, instead of burning it in an Argand lamp.

Rape oil has been tried in France for producing oil gas; but contained so much sulphuretted hydrogen gas, that its use as been abandoned.

### *Coal-Tar Gas.*

The difficulty of selling the tar obtained in the manufacture of coal gas, led to attempt the use of it for making gas; but it was found to clog up the pipes with such abundance of carbonaceous matter, as occasioned its use to be speedily abandoned.

Messrs. Vere and Crane obviate this inconvenience by mixing steam with the volatilized products. The apparatus is the same as for coal gas, with the addition of two iron pipes, bent so as to form hydrostatic funnels, one of which is inserted into each end of the retort; and a sheet iron tray, which is introduced into the retort: the remainder of which is filled with broken bricks, the mouth is then closed up, as usual, and the retort heated.

The cock of a water cistern, placed in the front of the furnace, being then turned, the small stream that flows into the retort is instantly converted into steam, and passes through the dip pipes. The cock of the tar cistern, placed behind the furnace, is then opened, and some tar admitted, which falling on the red hot tray, is converted mostly into gas, and obliged to mix with the steam. By this very simple means, the impurities which rise with the gas are separated, and settle upon the broken bricks, and the gas passes into the dip pipes free from superabundant coaly matter.

The dish or tray must be changed as often as it gets filled with the residuum of the tar, and also the bricks as they get clogged.

## DENSE SIMPLE COMBUSTIBLES.

Of the substances arrangeable under this head, only two are the object of operative chemistry: namely, sulphur and phosphorus. For selenium is not hitherto found to be of any use while bore and silicon, if they belong to this genus, are in the same case, as well as potassium and sodium.

### *Sulphur, or Brimstone.*

A very large part of the sulphur used in the arts, is obtained from the cracks and crevices in volcanoes, where it collects by the condensation of the sulphurous vapours. This native sulphur is generally purer than that collected at the mines during the roasting of the ores.

As great quantities of sulphur are consumed in its various uses; it is also obtained by distillation from the ores that contain it in a large proportion, as iron pyrites.

Near Liege, a number of long earthen pipes, rather wider at one end than the other, and open at both ends, are placed across the chamber of a long narrow furnace, so that the narrowest end is rather lower than the other. This narrowest end is stopped with a star of baked clay, to prevent the pyrites from falling out, but allowing the sulphur and its vapour to pass. The vessels are then charged with 30 pounds each of pyrites, the wide end stopped with clay, and the fire being lighted, the sulphur runs out at the lower and narrow end into tubs or pots, filled with water.

Fig. 211

Fig. 212

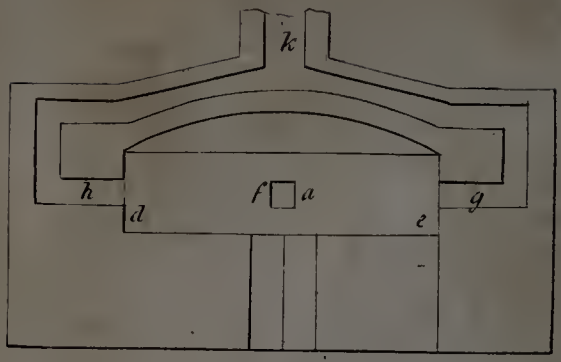


Fig. 213

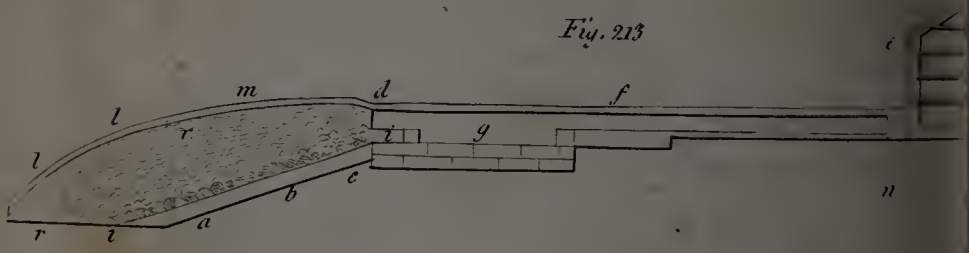



Fig. 214

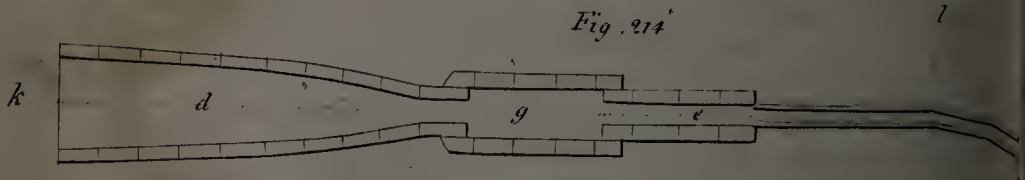



Fig. 215

It takes about 25 cwt. of iron pyrites to obtain one cwt. of ugh sulphur.

In some places, iron pyrites are distilled in large cast-iron torts.

Fig. 213, represents the vertical section of the furnace, which was invented Dr. Gahn, and has been used for some years at Fahlun, in Sweden, to ob- sulphur from iron pyrites; the section being in the line, *k*, *d*, and *n*, *o*, of 214, which is the plan of the furnace. In both these figures, the long chan- *f*, *e*, is broken off at *e*; if it were represented entire, the channel would be ut 42 feet long beyond the dotted line, *e*, *n*, before its turn round.

Fig. 215, is the vertical section, in the direction *q*, *p*, fig. 214.

Upon the slope, *a*, *b*, of a bank, *a*, *b*, *c*, pieces, *r*, of iron pyrites are placed n billets of wood, *i*, *i*. A channel, *d*, *f*, *e*, leads from the space, *r*. This nnel is covered with slabs of stone as far as *f*, and from hence unto the cham- it is formed of planks. A receiver, *g*, is placed at the beginning of this nnel. The chamber, *h*, is divided into five parts by horizontal divisions, ich allow a passage for the vapours from one division to the other.

The pyritous ore, *r*, having been piled on the billet wood, *i*, *i*; as soon as s is thoroughly on fire, the ore is covered with smaller ore, and afterwards h earth, *l*, *l*, heaped upon it; except that about the part, *m*, for the breadth a foot, the ore is covered with flags of stone. By moving these stones, the rning of the pile is regulated. Part of the sulphur distils into the receiver, from whence it is taken out occasionally; another part subliming, passes ng the channel, *f*, *e*, and into the chamber *h*, from whence it is taken out l washed with water, to separate the sulphuric acid with which it is some- es impregnated. After this washing, it is refined by distillation.

The ore from whence the sulphur has been thus separated, is used as a com- n red paint, much used for wood work.

The rough sulphur, or brimstone, is refined by distillation large cast-iron retorts, or in iron bodies, covered with rthen ware heads, containing about 6 cwt. of brimstone. hese distilling vessels communicate with earthenware recei- ers, with three openings; one on the side near the top to re- ive the neck of the distilling vessel, one at the top to let out e vapours which arise in great quantity, and the third near e bottom, by which the refined sulphur runs out in vessels led with water. Rough sulphur, or brimstone, loses about ne-eighth of its weight in this operation.

The refined sulphur thus obtained is melted, and poured into oulds of beech wood, well moistened with water.

Sulphur is for many purposes reduced to flowers, which is erformed in a sulphur-house, consisting of two rooms, one bove the other. The lower room contains a stack of furnaces, ith several iron pots, the fires being attended on the outside f the room. The sulphur is kept melted in these pots, and eing volatilized, ascends into the upper room through a large pening in the ceiling.

Brimstone, or rough sulphur, is also refined in a very thick ast-iron pot, capable of holding 10 or 12 cwt. of brimstone. his pot is covered with a hemispherical dome of brick work,

having two openings; one for the purpose of charging and d charging the pot, and which is closely stopped, and the joi luted at other times. The second opening communicates w a brick chamber on one side of the furnace: the size of t chamber is various. If it is proposed to manufacture roll s phur, the chamber need not measure more than 600 cubic f and it must have several gutters level with the floor, with st pers, to let the melted sulphur run out into the moulds. But manufacturing flowers of sulphur, the chamber must meas about 3000 cubic feet. In either case the chamber must ha on the side a man hole capable of being kept closely stopp and at top a trap, to let out the rarefied air. With chamb of this size 2 cwt. of brimstone may be distilled by the hot A pot an inch thick will last only four or five months, if constant use.

Sulphur is used in the manufacture of oil of vitriol, and burned in closets for bleaching. Sulphurous acid is obtain from it, and fire matches are tipped with it. The making gunpowder consumes an immense quantity.

### *Phosphorus.*

To obtain phosphorus 24 pounds of bone ash are put into a tub, and as m water added as to reduce it to the form of a thick soup, 20 pounds of o vitriol are then added, which renders the liquid much thicker, and more w must be added to dilute it, and the whole left for a day and night.

Boiling water is then added, the whole stirred up and left for some tim settle; the liquor at the top is taken off and filtered through canvas. Fr boiling water is added, and the filtering repeated until the water is no lon acid.

The solution of acid phosphate of lime which is thus obtained, contains s sulphate of lime; to get rid of which the water used for washing the bone must be evaporated in a leaden or copper boiler to the consistence of a syr the sulphate of lime separates as a sediment. To this concentrated liquor th or four times as much water is to be added, heated, the whole filtered, and t sulphate on the filter washed until the water has scarcely any taste.

The liquor that passes the filter is again evaporated to a syrup, and mix with ¼ its weight of charcoal powder, and calcined almost at a red heat i cast-iron pan, to dry it thoroughly, and prevent its puffing up when d tilled. The distilling vessel ought to be a stone ware retort, which may filled three-fourths or four-fifths of its capacity; to its neck is luted a copp pipe, which passing through a cork, goes down to the bottom of a large sto jar half filled with water; this jar is also furnished with a gas pipe passing throu the cork, ½ inch in diameter, and two or three feet long.

The furnace in which the retort is placed must give a very strong heat; t fire is brought on slowly, the phosphorus begins to come over in about fo hours, as is known by the phosphurated hydrogen gas that passes through t gas pipe taking fire, and the fire must be governed by the appearance of t flame. The whole operation usually takes up 24 or 30 hours, and each avoi pound of the phosphate produces an ounce ¼ of phosphorus, some of whi sticks to the copper pipe, and even to the neck of the retort.

The phosphorus being collected, is tied up close in a piece of chamois l ther, put into water nearly boiling, and strongly squeezed with pincers to for the phosphorus through the leather. When the water has cooled to about 1 deg. Fahr., glass pipes are dipped into the phosphorus, which is sucked up

mouth until it fills one-half or three-fourths of the pipe; the lower end of ich is then closed with the finger, and the pipe removed into a pail of cold ter that the phosphorus may set. It is afterwards pushed out from these pes, and preserved under water in a dark place.
Sometimes the phosphorus is redistilled in a glass retort: but not more than ee ounces should be distilled at once for fear of accidents.
Phosphorus is used only as a means of procuring a light.

## ARDENT SPIRITS.

These spirits are missible with water in any proportion, and hen pure totally inflammable.

The principal use of these spirits is as an exhilarating drink, too frequently used to produce drunkenness. They are also used to preserve animal and getable substances, by immersion in them; and the strongest and purest in e preparation of varnishes, and as a clean fuel to burn in lamps.

### *Common Brandy, or Spirit of Wine.*

This is the ardent spirit extracted from the high-coloured hite, or pale red wine, and forms one of the staple manufac-ires of the South of Europe.

The wines of the countries nearest the Mediterranean Sea, rnish the greatest proportion of brandy; and this proportion minishes as the grapes grow in more northern climates. The ines of the South of France yield one-fourth of brandy, some ven one-third; while in the North of France the wine yields nly one-eighth or even one-tenth.

White wines are preferred by distillers, not only because they ield more brandy than the red, and of a sweeter and better avour; but also because they fine sooner, and may be distilled efore the red are ready for the still. As they are not so much steemed for drinking as the red, they are also cheaper.

The body of the still being filled to three-fourths its capacity, he head fitted both to the body and worm, and the joints closed by wrapping a strip of pasteboard round them, and fastening it n by an iron hoop, drawn close by screws and nuts. The fire s lighted and brought on quickly, until the first spirit begins to listil, when the fire is slackened, and kept at an even pitch, so hat the spirit runs from the worm in a fine continued thread.

When nearly the expected quantity of spirit is distilled, the liquor that runs from the worm is assayed from time to time, either by the hydrometer, or by shaking in a phial and observ-ing the bead; or, which is most usual in large distilleries, by receiving some in a wine glass, throwing it on the still head, and applying a candle to it, to find whether when thus vapourized it takes fire. Some distillers have a cock in the body, which serves to show when it is full, and which they turn occasionally and apply a candle to the vapour that issues, for the same pur-

pose. When the vapour thus produced ceases to take fir, t brandy, or eau de vie, is reputed to have all come over, and fresh can being applied to the end of the worm, the *eau de seconde or repasse*, is generally collected separately, to t quantity of one-fourth of the first eau de vie; but if the bran is designed for home use, the worm, to use the French phras is not cut; but the seconds are allowed to mix with the first po tion. The liquor that remains in the still is called vinasse; a this being drawn off, a fresh portion of wine is poured into t still, and thus the distillation is continued without interruptio until all the wine is expended. In France, they only dis from the beginning of October to the end of May, and this th call a campaign.

Brandy is sold in France of two degrees of strength: namel Eau de vie a preuve de Hollande, and a preuve d' huile; tl first is very nearly 19 deg. of Baumé, and the second 23 d grees.

When a spirit of superior strength is required, the brandy re-distilled, and three quarters of it drawn over in the comm still, with a gentle heat, so that the thread from the worm m be extremely fine; and the spirit as it comes over is separat into different portions, as the strongest spirit comes over fir this distillation occupies two-thirds longer time than that of t same quantity of brandy. Some persons use a water bath.

These superior kinds of spirit are in France estimated by t quantity of Eau de vie à preuve de Hollande, that they w make by the addition of water, and are usually made of twel strengths, five-six, four-five, three-four, two-three, three-fiv four-seven, five-nine, six-eleven, three-six, three-seven, thre eight, and three-nine, but this last is rarely manufacture These apparent fractions are not to be read five-sixths, but fiv six; that is to say, five measures of this spirit will make six preuve de Hollande.

The spirit five-six, is allowed to be equal to 22 deg. Baum or sp. grav. 0·9237; but the other strengths are variable, in co sequence of the uncertainty respecting the strength of the spir preuve de Hollande, which varies from 18 deg. to 20 of Baum

The repasse, or eau de vie seconde, is also re-distilled; a 3 qrs. of it drawn over.

The vinasse still contains a little wine; it grows sour ver soon, and is used in some arts.

Spirit of wine, when first distilled, is as clear as water; ar if preserved in earthen or glass vessels, keeps its colour; but oak casks it becomes high coloured. Spirit is sold weak f the consumption of the neighbourhood; but when intended f distant markets, it is sold very strong, generally three-six,

ve the expense of carriage, and when it arrives at its place of nsumption, reduced by adding water or weak spirit.

Although brandy is a staple manufacture of France, their lls until the late improvements were very small, and still ntinue so in most places. The usual size is only 21 inches ep, 34 inches wide at top, and 30 at bottom; they are all tin- d on the inside, and covered with a plain moor's head of nned copper, or tin plate.

The consumption of fuel and produce has been thus stated:— 5 pounds of wine consumed in their distillation 60 pounds of t coal, and produced in 5 hours 42 minutes, 87½ pounds of u de vie preuve de Hollande, and in 2 hours more, 98 pounds repasses.

In re-distilling brandy, to avoid loss of the strong spirit by aporation, it is usual to receive it into a close barrel, joined the end of the worm by a lantern, which is two funnels sol- red together at their wide ends; and the upper funnel has two nall panes of glass let into it, that the thread of spirit may be en.

---

The improvements made in distilling spirit are of two kinds; ose relating to the common apparatus, in which spirits of su- erior strength is obtained by repeated distillations, and the still reater improvement of avoiding re-distillation, obtaining spirit f any required strength at once, and completely exhausting the ine, so that the vinasse is totally useless.

The improvement in the still body has been to make it large, ery wide, and shallow: some have made its bottom convex in- ernally, but the propriety of this form is disputed. The neck as been made very wide as well as the beak of the head, so as o allow a free passage to the vapour. It has also been found ad- antageous instead of a thick pewter pipe of small diameter for he worm, to use a tinned copper pipe of several inches in diame- er.

M. Poissonier, in 1779, proposed the following apparatus as he ultimate perfection of which the common still was suscepti- le; it is evidently taken from Weigel's Essays, which were ublished that year.

Fig. 216 is a perspective view of this apparatus. *A* is the body of the still, wo and a half feet in diameter, and close at top excepting the two openings *b* nd *c*. *B* is a round opening, a foot in diameter, in the middle of the top of he boiler, for the purpose of charging and cleansing the still. This opening as a double rim, and is closed by a cover, *b'*, which has also a double rim. The first drops of vapour that are condensed form a water joint. *C* is the fur- nace in which the still body is set, and *d* is the discharge cock. *E* is a square opening, six inches each way, towards the back of the still body: to this open- ng is soldered a square turned copper pipe of the same size, and as many feet long as the place will allow. This pipe serves as the head of the still, and also

as the condensing apparatus. *F* is a square copper pipe, in which the pip enclosed the greater part of its length: this pipe is an inch and half larger way than the inner pipe, which is kept in the middle by proper stays. T two pipes slope at the rate of half an inch in a foot. *G* is the partition wall tween the room, or shed containing the furnace, and that containing the c densing apparatus; to prevent the warmth of the fire from affecting the cond sation, or the odour of the vinasse discharged from the still, and which is quently very disagreeable, from affecting the brandy that is obtained. *H* tressels to support the condensing apparatus; and *i* are iron standards affixe the tressels to keep it in its place. *K*, is a pipe with a cock, soldered to the e of the pipe *e*, by which the spirit runs into the funnel, *l*, and is thus conveyed i the receiving tub, *m*. *N* is a leather hose, or pipe that transmits the water, u in cooling the vapours, from the cistern, *o*, to the lower end of the condens apparatus, between the two square pipes of which it is composed. *P* is a sm press composed of two pieces of wood, connected together by a screw, turning of which, the distance between the pieces may be altered at pleasu This press is used to regulate the flow of water through the hose, instead o cock. *Q* is the discharge pipe of the water employed in cooling; this pipe soldered to the top of the outer square pipe, and conveys the heated wa either to the sink or any other place.

This apparatus is stated to distil from 28 to 30 quarts of brandy by the ho but its produce would, of course, be much greater in proportion, if made o larger scale.

The still and condensing apparatus of M. Poissonier, or mo justly speaking, of Prof. Weigel's father, would probably h been gradually adopted by all the French distillers, if M. Ada a distiller of Nimes, attending a course of chemistry at Mont lier in 1799, had not conceived the idea of applying the c densing apparatus of Glauber and Wolfe in the distillation wine. His success was so great that a complete revolution h taken place in the apparatus, and the common stills with th various improvements, are only used by persons who distil t wines of their own growth, or by those distillers, the smallne of whose capital does not allow them to adopt the new appar tus.

The apparatus of M. Adam led the way. That of M. So mani, a physician of Nimes, who formerly lectured on chem try and experimental philosophy, and disputes the priority invention with M. Adam, although his brevet is dated a fe days later in July, 1801: and that of M. Berard, a distiller Grand Gallargues, also of the department du Gard, brevet 16th of August, 1805, which is perfectly original, are here d scribed, and all the other apparatus hitherto proposed may b considered as mere variations or combinations of these three.

The apparatus of M. Adam is the most in use; which is n through its superior merit, for it is considerably inferior to th other two, but from his litigious disposition; for having obtaine a brevet "for obtaining from wine all the alcohol it contain he considered all improvements in distillation within its reac and prosecuted every person who used any apparatus but h own for this purpose; so that the distillers were afraid to adop

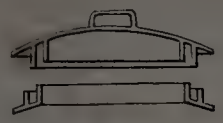


Fig. 216

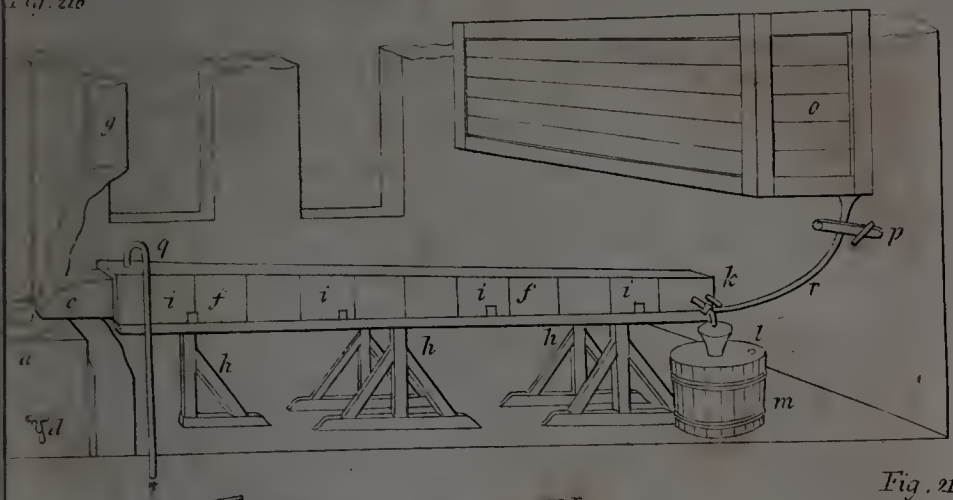


Fig. 217

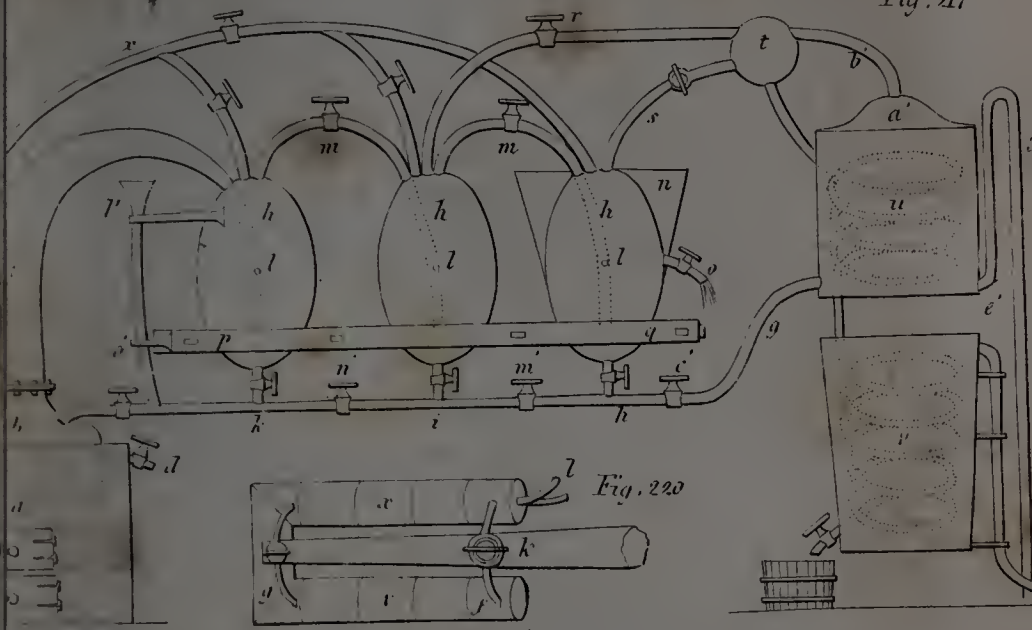


Fig. 220



Fig. 219

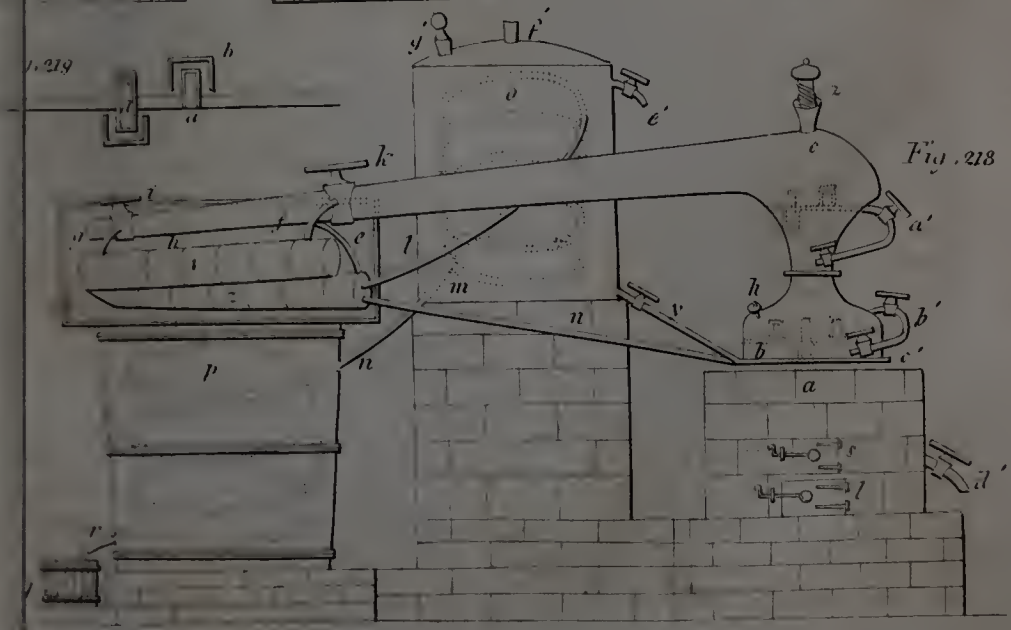


Fig. 218

y other, as it would have involved them in a law suit; and ose who have thus got this apparatus continue to use it. This igious disposition of M. Adam was its own punishment; for af- r having acquired a handsome fortune by his own distillery, was ruined by the expenses of the numerous law suits in hich he engaged, and which after years of litigation most com- only terminated against him, and he was condemned to pay e whole costs of the suits.

All these improvements are founded on these principles. Vine consists of a mixture of water and alcohol, which ingre- ents differ in the temperature at which their vapours condense to a liquid. The condensing part of the distilling apparatus eing then divided into two portions, and that next the still body ept at the temperature at which the vapour of water condenses, becomes a liquid, and is made to flow back into the body, hile the vapour of the alcohol not being condensable by this mperature, pass on to the second portion of the condensing pparatus, which is kept at a lower temperature, and here it is lso condensed and made to flow out into the receiver.

The original apparatus of M. Adam was a clumsy imitation f Glauber, but he afterwards simplified it.

Fig. 217, exhibits a view of his simplified apparatus, without the frame work ecessary to support the various parts. It is represented with three eggs, al- ough a few distillers use four, and his original apparatus had six or eight. *A*, is the furnace in which is set the body of the still, *b*. *C* is the discharge ock of the still. *D*, is another cock, placed at two-thirds the height of the ody, to show when the still is filled so far. *E*, is a small pipe from the neck f the still to the long pipe, *x*, which connects the last egg with a small worm ontained in a tub, *f*, for the purpose of proving the vapours contained in each f the distilling vessels; this worm has a cock, *g*, to close it. *H*, are three dis- illing vessels, in the form of eggs, fixed upon a frame, *p*, *q*. The body of the till communicates with the first egg, by the pipe, *i*, serving as a head to the till; this pipe goes to the bottom of the egg, and has at the end a rose, like that f a gardener's watering pot, the holes being about one-eighth of an inch in iameter. *L* are cocks, to show when the eggs are half full. The first egg communicates with the second, and the second with the third, by the pipes, *m*, ach of which go from the top of the egg to the bottom of the next, and have oses at their ends. The third egg is furnished with a bucket, *n*, soldered to ts upper end, and filled with water to condense the vapours; this bucket has a cock, *o*, to discharge the water when too hot. When the apparatus is furnished with four eggs, the two last have refrigeratories. *R*, is a pipe that connects the second egg with the globular vessel, *t*, and of course with the great worm, when only two eggs are used, in order to distil brandy à preuve de Hollande. *S*, is a pipe that connects the third egg with the globular vessel, *t*, and great worm. *U*, is a close vessel, which contains the first part of the great worm; the vessel s filled with wine, by means of the pipe, *y'*, which is connected with a forcing pump fixed in the stone cistern containing the wine. *V*, is a large tub contain- ng the second and larger part of the worm; this tub is filled with water by means of a pipe entering into it towards the bottom, and not shown in the figure; as the water grows warm, it rises in the tub, and is discharged by the pipe, *c'*. *A'*, is the head of the vessel, *u*, furnished with a pipe, *b'*, to convey the vapour of the heated wine into the globular vessel, *t;* there is a continua- tion of this pipe, not expressed in the figure, by means of which the vapour

may be conveyed either into the body of the still, or into one of the eg pleasure. $G'$ is a pipe connecting the vessel, $u$, of heated wine, with the bod of the still, and each of the eggs. $H'$, $i'$, $k'$, are cocks to regulate the connex ion between the eggs and the pipe, $g'$. $L'$, $m'$, $n'$ $o'$, are cocks to regulate th connexion of each egg, either with the vessel, $u$, to charge them, or with th body of the still, to discharge them. $P'$, is a funnel, by which brandy or re passe is charged either into the body of the still, or the eggs; this cornucopi as it is called, is fixed to the first egg, and the egg frame, $p$, $q$, by iron stays The whole apparatus is made of tinned copper, and the pipes soldered together

## Although this apparatus has always a bucket to the last egg or two, many distillers think them useless, and do not use them even when they intend to obtain only spirit of wine three-six.

The operation is begun by opening the cocks, $m$, $s$, $d'$, $h'$, $m'$, $n'$, $o'$, and pumping wine into the vessel, $u$, until it begins to run out of the cock, $d$, which is then shut, as also $o'$; and $k'$ is opened as also the cock, $l$, of the first egg The wine then is forced into the first egg, and as soon as it runs out of the cock, $l$, the cocks $n'$, $k'$, and $l'$, are shut; and $i$, is opened, as also the cock o the second egg; thus the wine is forced into the second egg, and as soon as i runs out by the cock, $l$, the cocks, $n'$, $i'$, and $l$, are shut, as also $l'$; and the pumping is continued until the vessel, $u$, is nearly filled. The refrigeratory o the condensing egg, $n$, is then filled with water, as also the tub, $v$.

The apparatus being thus filled, the fire is lighted, and the vapours of th wine pass into the first egg, where some part being condensed, heats the wi in it, and its vapour joined with the other, pass on to the second egg, and fro thence to the third egg, or condenser, where part is condensed, and the rem der goes on to the worm, and flows into the receiving tub.

The strength of the vapour arising from the body of the still, or any of t eggs, is tried by opening the communication between them and the small worm $f$, and cutting off that to the large worm, in $u$ and $v$; the spirit being receive in a glass, is examined either by the hydrometer, or otherways. When t liquor in the body of the still is exhausted, the fire is withdrawn, the comm nication with the eggs, or great worm, is shut, and the discharge cock, opened. If it also appears that the liquor in any of the eggs is exhausted, is run off at the same time by opening the necessary cocks; but the liquor those that are not exhausted, is run into the body of the still, and the filling the body is completed by adding some repasse, by the cornucopiæ or wine, fro the vessel, $u$. The first two, or distilling eggs, are then filled either with wi from the vessel, $u$, or if it is intended to obtain a strong spirit, with brandy, by the cornucopiæ.

As the passage of the vapours through the liquor in the eggs, occasions great expansive force within the body of the still, it must be made stronge than ordinary.

## Dr. Solimani's still is evidently distillation by steam, with a highly improved condensing apparatus.

Fig. 221, represents a geometrical elevation of Dr. Solimani's still, being part of a set of two stills, placed on each side of a chimney, $t$, and cooler, common to both; in the still not shown in the figure, all the parts are of cours reversed in situation, the fire being at the end farthest from the chimney. Fig 222, is a section of the same.

$A$, is a pipe to convey wine from its cistern into the stills, by means of th cock, $b$, and the pipe, $c$. $D$, are two still bodies, 4 feet square, and only 1 inches deep, but connected together by a pipe, $e'$. The necks are cylindrical nearly 3 feet wide, and just long enough to pass through the stone vault, $f'$ On these necks are placed low heads, with wide beaks, $g'$, which are soldered to a pipe, $e$, by which the vapours are forced to descend to the bottom of th close copper barrel, $f$, where part of them being condensed, form a stratum o

ter, through which the succeeding vapour is obliged to pass. *G*, is a wide pe, which conveys the vapours from the vessel, *f*, into the dephlegmator, or ogene, contained in the tub, *h*.

This dephlegmator is formed of two broad sheets of tinned copper, soldered gether so as to leave only one-sixth of an inch between them, and bent into ir inclined planes, as shown in the adjoining section, fig. 224. It is enclosed a tub of water, which is kept at a uniform temperature by a regulating appara- s hereafter described. *I*, is a pipe that conveys the vapours not condensed the dephlegmator, into the refrigeratory contained in the water cistern, *y*. he refrigeratory is formed like the dephlegmator, of broad sheets of tinned pper, soldered at a small distance from each other, and forming six inclined anes, as in the adjoining section, fig. 223; the spirit being condensed in this frigeratory, flows out by the pipe, *k*. *L*, is the pipe that supplies the regu- ing apparatus of the tub in which the dephlegmator is placed, with cold wa- . *M*, is a bent pipe, to convey the phlegm collected in *f*, when it reaches e level of the bend of the pipe, into the pump tub, *n*. *O*, is the handle of oreing pump, by which the phlegm is returned into the still bodies, by ans of the pipe, *v*. *P*, is a door, by which a workman can get into the fur- ce, to repair it. *Q*, is the door into the fire room, which is only a foot uare. *R*, is the ash room door. *S*, is the receiving can. *T*, the chimney, hich serves for both furnaces. *V*, is the pipe by which the phlegm is con- yed back into the body of the still. *X*, is the pipe that conveys cold wa- r from a cistern into the refrigeratory cistern, *y*, and the vessel in which the phlegmator is placed. *Y*, is a stone cistern, containing the refrigeratories of e two stills. *Z*, is a pipe to convey the steam into the chimney.

*A*, is a flat shallow copper boiler, about 10 feet long and 4½ feet wide: it ntains only about 8 or 12 inches deep of water, whose steam is employed to at the still bodies, supported over it by the iron bars, *c'*. *B'* is part of the ue under the boiler, which is eight inches square at the fire room, and grows haller by degrees: it is passed from side to side, so as to be nearly 36 feet ng before it reaches the chimney. *C*, are the iron bars that support the ill bodies: the boiler being firmly fixed in the walls and covered with a stone ch, *f*, in which is a steam pipe, *z*, that conveys the steam of the water in e boiler into the chimney, *t*. *D*, is a glass pipe cemented into a copper pipe nnected with the boiler, to show the depth of water in it. *E'* is a pipe that nnects the two still bodies together. *F'*, is the stone vault confining the eam. *G'* are the beaks of the stills resting on the stone vault. *H'* is a ipe bent upwards, with a cock, and funnel by which to convey water into e boiler, *a'* when wanted. *I'* is the discharge cock of the still body. *K*, is glass pipe like *d'* to show the depth of wine in the bodies. *L*, the waste ipe of the dephlegmator tub, and *m'* that of the refrigerator cistern. Fig. 25 represents the regulating apparatus, fitted in the tub *h*, drawn on a large cale. *A*, is a section of the tub on one side of the dephlegmator, or aleogene. , is a box fixed on the side at the bottom. *C*, is a valve of at least a suffi- ient weight to resist the pressure of the water entering the tub by the pipe, . *E*, is the level at which the water is kept by the waste pipe, *f*. *G*, *h*, is floating ball, bearing on its upper stem, *i*, *k*, a basin, *g*, for weights. *L*, *h*, the lower stem of the float, with a ring at the bottom. *M*, *n*, a sliding rod assing through the side of the vessel, and supported by the bracket, *o*, *p*: this od has a ring at the end, *m*, through which the upper stem of the float asses, and by which it is kept upright. *Q*, *r*, is another rod, with a knob at he end, *q*, and a hook at the end, *r*, to which hangs the valve, *c*. *S*, *t*, is an pright stem, with a ring at the upper end, *t*, through which passes the rod, *q*, . *V*, is the water way stopped by the valve *c*. *U*, is the stem by which the alve, *c*, hangs on the hook, *r*. *X*, *y*, is a horizontal stem fixed in the side of he vessel, and with a ring at the end, *x*, through which passes the stem, *u*.

The action of this regulator depends on the specific gravity of the water de- reasing as its temperature increases, and hence the floating ball descends. The basin therefore is loaded so that at the temperature at which it is desired to keep the water in which the dephlegmator is plunged, it shall be an exact

counterpoise to the upward pressure of the water on the valve, *c*. When water gets warmer the float descends, and by its lower stem, *l*, *h*, lowers end, *q*, *t*, of the lever, *q*, *r*, and thus raising the end, *t*, *r*, causes the valv rise up and admit the cold water, until the temperature of the whole is so l ered, that the float rising, by an opposite movement shuts the valve. I should be found that it requires a great change of temperature to cause float and valve to act, the rod, *m*, $n_1$ is to be pushed farther into the ves and at the same time the lower stem of the float is to be pushed more towa the end, *q*, of the lever, *q*, *r*; the float being thus made to act by a longer ver, it will be enabled to lift up the valve with a less force, and the water be kept at a more uniform temperature.

The boiler is first filled with water through the pipe, *h'*, to the proper hei as shown by the gauge pipe, *d'*, and the fire lighted. In the mean time w is run into the still bodies by turning the cock, *b*, until they are filled at necks, as shown by the gauge pipe, *k'*. The steam of the water heating still bodies, the vapours of the wine rise into the heads, and are forced to scend the pipe, *e*, into the vessel, *f*, where part of the watery vapours are c densed, and lodged on the bottom of that vessel until the phlegm rising ab the level of the arch of the syphon, *m*, it runs into the vessel, *n*, from whe it is occasionally pumped up the pipe, *v*, into the still body again to be c pletely exhausted. The uncondensed vapours pass through the pipe, *g*, i the lower part of the dephlegmator, where the remainder of the watery pour is condensed, and flows down through *g*, into *n*; and the vapours of spirit pass into the refrigeratory, where they are also condensed, and f out into the receiving can. The quality of the spirit is determined by the t perature at which the water is kept, in which the dephlegmator or alcogen plunged. If this temperature is 130 or 136 deg. Fahr. the spirit will be o strength three-five or three-six.

When the phlegm which separates from the alcohol, and runs into th ceiver, *n*, appears to be totally exhausted, it is no longer pumped into the bodies, but rejected as useless; and a fresh parcel of wine is let into the boi by turning the cock, *b*, and thus the distillation is continued without any i ruption until the vinasse in the still bodies becomes so loaded with tartar colouring matter, that there is danger of its furring them, and hence it r be let out by the discharge cock, *i'*, and the bodies washed by pum warm water into them.

Comparative trials were made with this apparatus, and th used by other distillers. Six cwt. of wine distilled in the st of Messrs. Argand, and in stills constructed upon M. Chapt principles, yielded in nine hours, from one-fifth to one-th their weight in brandy, à preuve de Hollande. In the sa space of nine hours, Dr. Solimani's apparatus converted 1 cwt. of wine into one-sixth its weight of spirit at three-s with the expenditure of 3 cwt. of fuel. So that in an eq time, and with two-thirds of fuel, Solimani's apparatus distil 18 times as much wine into strong spirit as the best comm stills could convert into ordinary brandy.

It owes this advantage to the flat form of the dephlegmat which exposes a thin sheet of vapour, in a horizontal positi to the cooling action of the water. A dephlegmator co posed of four sheets of copper, only 18 inches square, placed so close as to take up only 26½ inches in height, re fied, in 16 hours, 600 veltes, 17½ lbs. each, of brandy i strong spirit.

Fig. 221

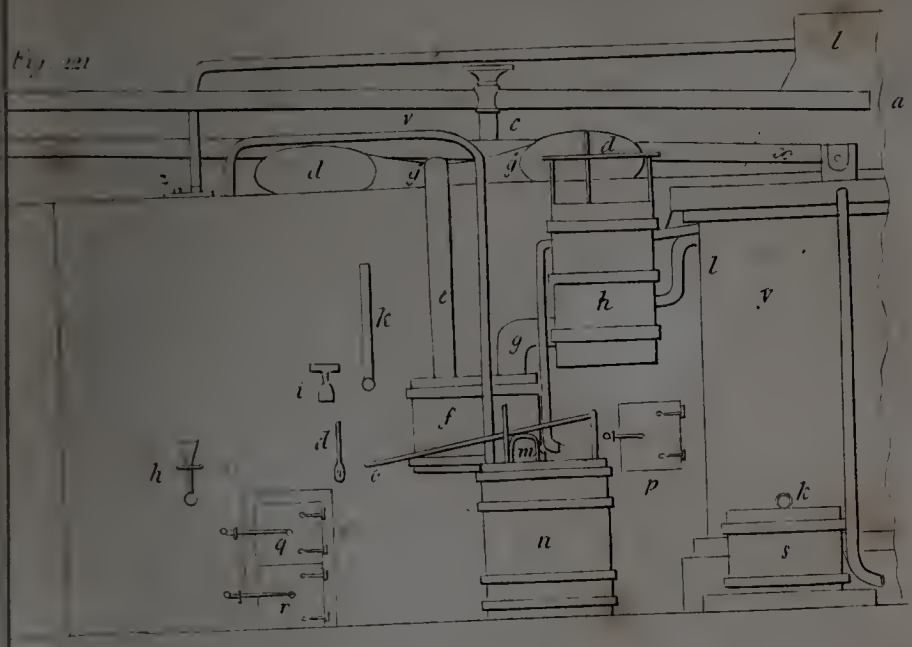



Fig. 222.

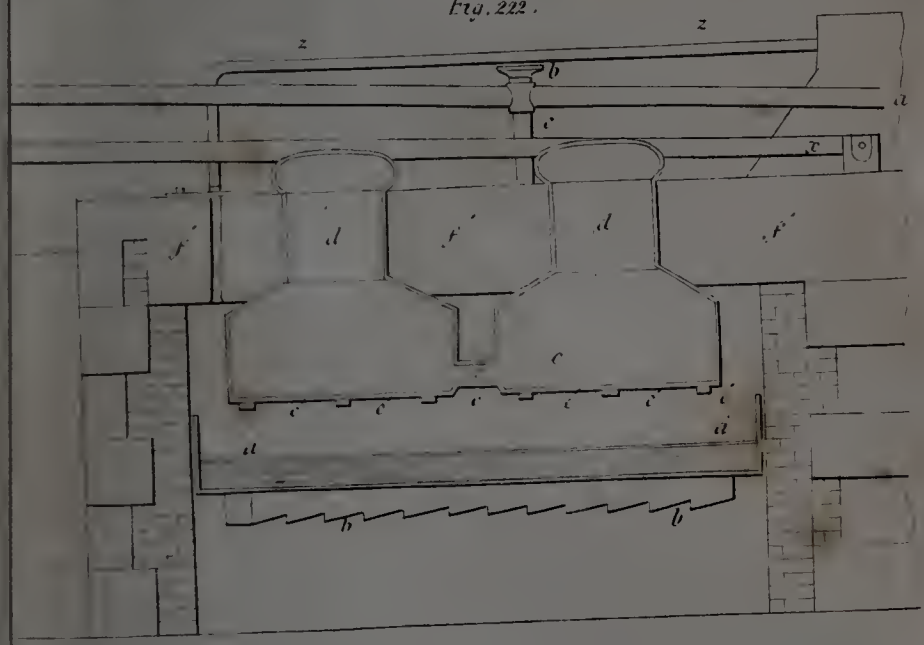



Fig. 223

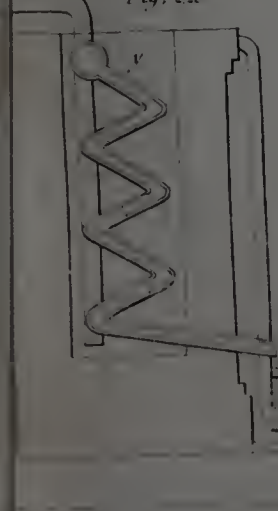



Fig. 224

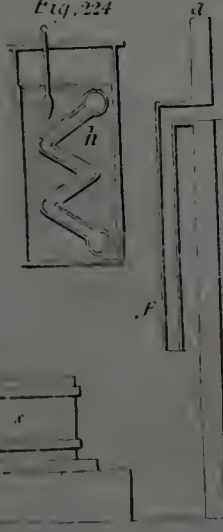
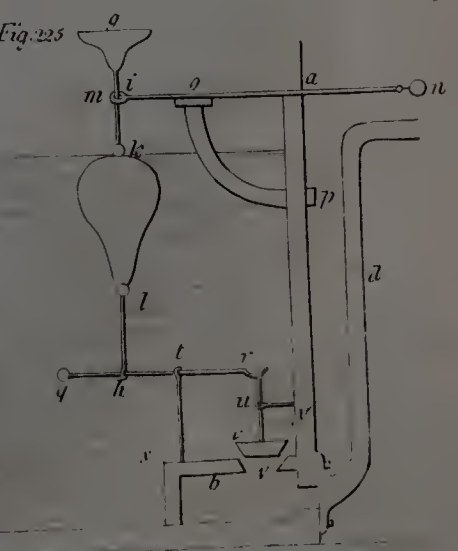



Fig. 225



As the steam is worked at the usual pressure of the atmos-ere only, the heat communicated to the liquor in the still dies is never entirely equal to that of boiling water; and, ving to this circumstance, the flavour of the spirit is so good to make a difference of 5 per cent. in the price. M. aptal's report mentions the adapting of a loaded safety valve the boiler, to work with hotter steam; but this would re-ire additional apparatus, and, probably, diminish the fine vour of the spirit by raising the essential oil of the grape.

Fig. 218, represents the apparatus of M. Berard. *A*, is the furnace in which e body of the still, *b*, is set. *C*, is the head; the dotted lines in the top of e still body and in the head represents the diaphragms with their condensing pes and safety pipes; the construction of which are shown more at large in . 219. *D*, is the beak of the head, which is made very large, and furnished th two cocks, *k*, *i*, both of which have double passages. *E*, is a pipe pro-eding from the beak to the hither end of the lowest branch, *x*, of the con-nser. *F*, is another pipe proceeding from the beak, but ending in the hither d of the highest branch, *v*, of the condenser. *G*. is a pipe proceeding from e lower cock, *i*, of the beak to the farther end of the highest branch, *v*, of e condenser. *H*, is a similar pipe the farther end of the lowest branch, *x*, of e condenser. *I*, is a large cock with a double passage, by the turning of hich the vapours are directed through the pipes, *g*, or *h*, either into the ghest or lowest branch of the condenser at pleasure, or these passages are tirely stopped. *K*, is another large cock with two ways; by turning of hich the vapours are either allowed to pass on to the end of the beak, or forced rough the pipe, *f*, into the hither end of the upper branch, *v*, of the con-nser. When *k* allows the vapours to proceed along the beak and the cock, is turned so that the passage into either of the pipes, *g*, or *h*, are stopped, e vapours are forced by the pipe, *e*, into the hither end of the lowest branch, of the condenser. *L*, is the pipe which conveys the uncondensed vapours om the lowest branch, *x*, of the condenser to the first worm. *M*, and *n*, is e pipe that connects the first and second worm. *O*, is a tinned copper ves-l, in which the first worm is placed; this vessel is filled with the wine that next to be distilled, and is closed at top, but has a pipe, *f*, not fully ex-ressed in the figure, which, by means of branches and cocks, conveys at easure the vapour into any of the four ends of the condenser. *P*, is an pen tub containing the water in which the second worm is placed; this tub rves as a support for the trough of water in which the condenser, *v*, *x*, is nk, and entirely covered. *Q*, is the vessel which receives the spirit from e lower end, *r*, of the second worm. *S*, is the fire door of the furnace. *T*, is e ash room door. *U*, is the pipe that conveys the phlegm condensed in the ondenser back into the body of the still. *V*, is the highest branch, and *x*, e lowest branch of the condenser, as it lies sloping in the trough of water, allow the condensed phlegm to run from the end, *f*, to the end, *e*.

This condenser, of which a bird's eye view is given at fig. 220, and marked ith the same letters, is composed of two branches, *v*, and *x*, and an interme-iate piece to join them. The branches are three feet long and six inches in ameter; the intermediate piece is only 18 inches long, so that the branches re that distance apart. The condenser is divided internally into 13 parts by artitions, which have each of them a round hole on the side alternately right nd left to allow the vapours to pass from one partition to another, and a se-icircular hole in their lowest part to allow the condensed phlegm to run om those that lie the highest into the others, and from thence into the pipe, . The water with which the condenser is entirely covered, is kept at 122° ahrenheit.

*Y*, is a pipe with a cock by which the wine in *o*, is conveyed into the body

of the still when a new distillation is to be begun. *Z*, is a short p... screw stopper, by which, when a course of distillation is first begu... wire is introduced to lodge upon the diaphragms in the head and bo... still, in order to ensure the immediate action of this apparatus. *A'* i... with two cocks, to pass the phlegm condensed on the diaphragm in th... of the head into the lower part. *B'* is a similar pipe, to pass the phl... densed on the diaphragm in the upper part of the still body into the lo... *C'* is the lower cock of the pipe, *b'*, and has two ways, in order that it ... show when the body of the still is sufficiently filled with wine. *D'* is the charge cock of the still body. *E'* is the gauge cock of the wine ves..., ... show when it is full. *F'* is the beginning of the pipes from the ves..., ... the condenser. *G'* is a short pipe with a screw stopper, by which t... sel, *o*, is filled. And *h'* is a similar pipe by which the body of the sti... filled.

Fig. 219, represents a section of the diaphragms in the head and body ... larger scale. *A*, is one of the condensing pipes, six inches long and two w... This is covered with a cap, *b*, of the same length, but three inches wide, ... supported by three fastenings at about half an inch from the diaphragm. ... is one of the safety pipes, a foot long, soldered in its middle to the di... phra... The lower end has a cap similar to those that cover the condensing pipes, the upper end is pierced with two rows of holes, the lower of which are ab... three inches above the diaphragm. Each of the diaphragms has a saf... ty p... in the centre, and three condensing pipes in the circumference: but if the ... is made larger, more condensing pipes must be used, and the safety pipes ... creased in proportion.

The gauge cock, *c'*, being left open, wine runs into the still body by the ... *h'*, through a funnel until it runs out at the gauge cock, *c'*. Some wi... poured in at the pipe, *z*, to lodge on the diaphragms in the head and b... the still. The vessel *o* is then filled with wine by the pipe *g'*, until it run... by the gauge cock, *e'*. The trough in which the condenser is placed is ... with warm water at 122° Fahr. and the cooler, *p*, with cold water.

The fire is then lighted, and the distillation begun as quickly as possibl... the strongest spirit that the apparatus will yield is to be obtained, the coc... is turned so as to prevent the vapour from proceeding farther along the b... and to force it through the pipe, *f*, into the condenser. The vapours of wine are thus obliged to pass through the wine on the diaphragms in the ... and head of the still, by which some of the watery vapours are condensed, flow back again through the safety pipe into the still body. The uncondens... vapours then pass along the beak, and are forced through the whole lengt... the condenser, *v*, *x*, which, being kept at the uniform temperature of 1... Fahr. condenses the greater part of the watery vapours which flow back ... the still body by the pipe, *u*, and allows those of the spirit to pass into ... worms by the pipe, *l*, and from thence into the receiver, *q*. If a spirit of ... strength is required, the cock, *k*, is turned to shut the pipe, *f*, and allow ... vapours of the wine to pass along the beak to the cock, *i*, which is turned ... as to pass them through the pipe, *g*. In this case the vapours pass only thro... the intermediate and lowest, branch, *x*, of the condenser; and less of the ... tery vapour being condensed therein, the remainder passes along with the ... pour of the spirit into the worms. If still weaker spirit is only required, ... cock, *i*, is turned so as to force the vapour through the pipe, *h*, and of co... through the lowest branch, *x*, of the condenser. Lastly, if it is intended to ... tain a very weak spirit, the cock, *i*, is shut, and *k*, opened so as to send the ... rit through the pipe, *e*, into the last partition only of the condenser.

The spirit that flows into the receiver is examined from time to time, ... when the distillation of a charge is finished, the fire is withdrawn, the vin... runs out by the discharge cock, *d'*, and the body charged afresh, by open... the cock, *y*.

The cocks on the pipes, *a'*, *b'*, are only opened when it is apprehended th... may be more phlegm on the diaphragm than can run off by the safety p... They seem to have been used in the stills made before the invention of the s...

pipes in the diaphragms, but are now a needless incumbrance; and a simple ige cock at *c*, is all that is necessary.

Ten veltes of Touraine white wine, one of the worst wines to stil, yielded, on a public trial, spirit of any required strength pleasure, and these different parcels mixed together made up velte, seven-eighths of brandy, á preuve de Hollande, with degrees of surforce. This brandy put into the still yielded, a second trial, the whole of its alcohol, in spirit three-ghths, the strongest that is kept for sale. The two trials cupied 2 hours. In the common mode Touraine white wine elds one-eighth less brandy, and that not full proof.

### *Cogniac Brandy*, or *best Spirit of Wine.*

This is obtained by distilling the palest white wines in the dinary still by a gentle heat, so as to avoid raising the essen-l oil contained in the skin of the grape.

It may also be obtained by distilling other white wines, or en the paler red wines in Solimani's apparatus.

It is sometimes kept in glass bottles, or stone ware vessels r sale, in order to prevent its tasting of the cask, or acquiring colour, and to retain its flavour of musk; but this retards its tting rid of the fieriness of new brandy.

### *Inferior Brandy*, or *Eau de Vie de Marc.*

This spirit is known by the hot fiery taste of the essential il of the grape, with which it is impregnated. It generally lls for one-fourth or one-third less price than that of ordinary randy. It is drank by the lower class of people in France, nd preferred by the English and other northern nations, on ccount of its taste being similar to that of the hot oily kinds f spirit made by them from corn, potatoes, and other sub-tances.

It is made by distilling the dark red wines of Portugal, pain, and other countries; as also the lees deposited by wine n keeping, the scrapings of wine casks, the skins or grains f common raisins deposited in the making of raisin wine, he cake left in pressing grapes, and the lees left in making vi-egar.

The distillation of the wines is performed as usual, but as he taste of the spirit is not regarded, it is hurried on fast.

The cake left on pressing grapes is prepared for distillation y being broken to pieces, and thrown into large covered tubs, vater is then added, the mixture soon ferments, and when the ermentation is complete the liquor is distilled in the ordinary

stills. The produce of the first distillation is of a whitish colour, and hence called *blanquette*, this is distilled again, and yields a spirit at 22 or 24 deg. Baumé. It takes 84 or 85 pounds of the grape cake to produce one pound of brandy.

In some places, the grape cake is broken, flung into pits, and covered with earth; the process of the fermentation is judged by thrusting the arm into the heap. When ready, it is taken out of the pits, mixed with water, and distilled. In this manner, 90 or 100 pounds of grape cake are required to yield a pound of brandy.

These liquors are peculiarly apt to burn to the bottom of the still, and hence to have the taste of the spirit still more depraved by the addition of a smoky flavour. Several attempts have been made to avoid this inconvenience. Devanne proposed stirrers to keep the liquor in continual agitation, and prevent the sediment from adhering to the bottom of the still; but this requires a complicated form to be given to the still. Some distil their wine lees in a water bath, and Baumé used a basket to be placed in the still body, into which the thick liquor was poured, and thus the sediment was retained in the basket. The vinegar makers at Paris drain their lees, and when no more liquid will run, put the remainder into sacks, and press out the liquor, which is mixed with the former, and distilled.

M. Reboul has established a distillery for grape cake. His still bodies are large wooden casks, to which are adapted worms of the usual form, and he heats the thick liquor by introducing steam into it from a boiler, placed in the centre of his still house.

M. Curaudau distils wine lees in a still whose neck is a separate piece, as wide as the still body, and three feet long. brackets are made on the inside, to support several partitions, at nine inches apart. Each of these partitions have several small short pipes, to allow the vapours to pass freely, and are pierced with a number of small holes. The neck being put in the still body, and the lowest partition put in, some of the wine lees are poured in, the liquid part drains into the still body, the thick part remains on the partition: another partition is then put in, and more lees, and so on, until all the partitions are covered, about six inches deep with the thick matter of the lees. If the liquor that drains from them is not sufficient to fill the still body, water is added. The distillation being begun, the steam heats the several layers, and causes them to give out their spirit.

As most of these liquors contain an acid that unites with the essential oil of the grape, and depraves the taste of the spirit

is proper to add limestone to separate this acid; or, which still better, quicklime, which will also absorb some of the il.

The thick grouty matter left in these distillations, or the cake ft on pressing the lees, is dried and burned for its alkali, hich is sold by the name of *cendres gravellées*, and is es-emed by the French dyers as preferable to potash or pearl-sh.

The physeter of Mr. Field, would be very useful in the anufacture of common brandy from these grouty materials.

Fig. 233, represents a section of the physeter, or percolator; and fig. 234, the elevation of the same. *A*, is a strong tub, with iron hoops, moveable pon castors. *B*, is a wooden hoop, fixed on the inside, a few inches from the ottom. *C*, is a strainer, resting upon the hoop, *b;* that represented in the gure is a sieve of copper wire. *D*, is a small lifting pump, placed on the out-de of the tub, and communicating with the lower part. *E*, in the side figure, ows the copper sieve, covered first with a baize strainer, and over that ano-er of the silk called lute-string, to show how the edges of these are secured y being turned over the rim of the strainer; the space left between them and e side of the tub, is secured by a list of woollen cloth, and the whole fastened own by the hoop, *f*, which fits so closely to the sides of the tub when driven own, as to render the whole air tight. *G*, is a funnel cock, by which the wer part of the tub may, if required, be filled with water. *H*, is another ck, by which the air in the lower part may be let out while it is filling with ater, by the cock, *g;* or the air let in it, if the purpose for which it was ex-austed by the pump, is answered.

Sheets of filtering paper may be placed between the cloths of the strainer, r the number of these may be increased; and if a copper wire strainer is dged improper, a wooden grating may be substituted.

As the action of the pump occasions the atmosphere to press pon the surface of the liquor, at the rate of 14 pounds to every quare inch of surface, this apparatus is very powerful in forc-ng liquids through several layers of filters, or filtering pow-lers, or in draining the last portions of liquor from spongy substances, which would otherwise retain a large portion of the iquid with which they are impregnated.

## *Potato Spirit.*

The potatos best adapted for distillation, are those that con-ain the most fecula; of which, in an average, they contain ne quarter of their weight. It was a great inconvenience in heir use, that they could at first only be employed from Octo-ber to May; but means have now been found to avoid this de-fect.

The first method is, to boil the potatos by steam; this is done in France, a ton weight at a time, in one hour, and they are then reduced to a mash, in the same time.

In a working tun capable of holding at least 350 gallons, there

are put 8 cwt. of the mashed potatos, and ½ cwt. of malt, with sufficient quantity of hot water, that the heat of the mash may be 95 deg. Fahr. and the whole is well stirred. In half an hour, more boiling water is added, to raise the heat to 131 deg. Fahr. Two or three hours afterwards, hot and cold water is added, so that the heat may be 77 deg. Fahr. and the mash made up to 300 gallons. A quart of good beer yeast is then added, which produces the necessary fermentation, and when this is perfected, the whole is put into this still. In this method, it requires the particular apparatus already described, to prevent the spirit from acquiring a bad flavour, by the feculent matter adhering to the still.

The second method is, to put 8 cwt. of raw potatos, grated to a pulp in a mill, into a mash tub of 200 gallons, with a false bottom and straw between the bottoms. In half an hour, the water that has run from the pulp, is let off, and about 120 gallons of hot water is added, as also ½ cwt. of malt, and the whole well stirred. In three or four hours, the clear wort is drawn off into the working tun, which need only contain 280 gallons. Fifty gallons of hot water are then added to the potatos, and this being drawn off, another 50 gallons of cold water is poured on the potatos, drawn off, and added to the warm mash, when it cools to the proper temperature; and this is fermented with yeast, and distilled as usual.

The pulp retains about three-fourths its weight of wort which might be extracted by the press; but it is usually left to render the pulp better for the animals who are fed upon it.

The third method, invented by Kirchoff in 1811, is to convert potato starch into syrup by oil of vitriol. For fermenting 6 cwt. of potato starch, the mashing tub, which must be lined with lead, should contain 500 gallons, be covered at top, except a trap, furnished with a stirrer, having several wings, and two discharge cocks, one even with the bottom, the other about six inches above it: 150 gallons of water are put into this tub; and steam being conveyed into it from a boiler, by a leaden steam pipe, it is brought to 176 deg. Fahr. In the mean time, 6 cwt. of potato fecule are mixed in another tub with 12 cwt. of water, and 12 pounds of oil of vitriol; and this liquor is introduced at three or four times by the trap, into the hot water in the working tub, taking care that the water be brought to its original heat, before a fresh parcel is added, and also to heat it to that point at the end. The trap is then closed, and if it does fit well, is luted round with clay, and the whole left for six hours, care being taken to prevent its cooling too much; a glass of the liquor being then drawn off, tincture of iodine is added, and if a blue colour is produced, the sacchari-

ation of the fecule is not completed, and the whole must left for some time longer, and again assayed. The trap ing then opened, the oil of vitriol is neutralized by adding adually about 20 pounds of whiting, previously made into liquid with seven or eight gallons of water. The neutrali- tion is assayed by dipping a slip of litmus paper into the li- uor; as long as it is turned red, more whiting must be add- . The liquor is then left for about an hour to settle, when is drawn off clear by the upper discharge cock, and let into e fermenting tub. The sediment is let out by the lower cock, d thrown upon canvas filters; the liquor that drains from is added to the other, and fermented with yeast, and distilled the usual manner.

The fourth method, discovered by Cadet Gassicourt, in 1817, ffers only from the former by using steamed potatos, reduced pulp, instead of potato starch.

A fifth method, totally different, has been invented by Mr. emen, of Pyrmont, and has been adopted in Sweden and enmark. The potatos are heated by steam, and broken wn by a revolving iron cross, much finer than by pestles or rasping mill. The pulp is then mixed with hot water, and each ton weight of potatos is added a pound of potash, ndered caustic by quicklime. The pulp is cooled as quick possible, and to each three tons of potatos, is added half a n of malt, and the whole fermented as usual. This fermen- tion produces a very large quantity of excellent yeast, so as allow a profit to be also made by its sale.

The sixth method was invented to get rid of the trouble of ducing the potatos into starch, and yet preserve them fit for istillation all the year. The potatos are steamed and reduced a pulp, which is spread about an inch thick upon flat wicker askets, which are placed one upon another, in an oven or stove, ntil the pulp is perfectly dry. The dried pulp is kept until anted, when it is ground, sifted, and reduced to saccharine atter either by oil of vitriol or caustic potash, as in the for- er methods, fermented with malt, and afterwards distilled.

Potatos ferment quicker than corn, the mash being usually rought to the specific gravity, 1·036 to 1·044, and do not re- uire so much yeast to be added. Sometimes the pulp of the otato forms a dry head over the liquor, and does not allow any east to pass, but the fermentation goes on equally well.

Beet-roots or carrots steamed and ground with the potatos, mprove the flavour of the spirit.

Thirty-eight cwt. of potatos, with 200 gall. of malt, yield bout 225 gall. of spirit.

M. Oerstedt removes the green taste of potato spirit, by

adding about an ounce of oxymuriate of lime to each 10 g lons of spirit, and re-distilling it. As the strength of ox m riate of lime, called also bleaching powder, is very variable, is necessary to make a trial or two in a small assay still, f mixing any large quantity.

### *Malt Spirit, or Whiskey.*

This is generally prepared in England at present, by mixi 3840 gallons of rye or barley, ground very fine, and 12 lons of coarse ground pale malt, and making it into a m with 8500 gallons of water, heated to 170 deg. Fahr. The is then drawn off 1020 gallons of this wort, and a large q tity of yeast is added to it: and when the remaining wort cooled down to 55 deg. Fahr. 80 gallons of malt are ma h with another portion of 1020 gallons of hot water, and thi b ing drawn off, is mixed with the first wort, and the ye st wort is also added. This wash should have the specific g avit from 1·084 to 1·110. In the course of ten or twelve day , t specific gravity gradually diminishes till it becomes only 1·0 when the yeast head falls quite flat; the wash has a vinous sm and taste, and is fit for the still. It is calculated that eve y gallons of meal and malt ought to produce 18 gallons of spir so much stronger than proof spirit, that 10 gallons will ma 11 gallons proof, or about 1782 gallons of proof spirit in t whole.

In general, one-third of the wash is drawn over at the fir stilling, and the product is called low wines, the specific grav ty being about 0·975. On re-distilling the low wines, a milk fiery tasted spirit comes over at first; when the running tur clear, the spirit that has come over is returned into the stil The distillation being continued, the clean spirit comes ove and when the running gets below a certain specific gravity, th remaining spirit which comes over, until it ceases to be infla mable, is kept apart, by the name of faints, and is mixed wit the next parcel of low wines that are distilled.

The proportion of malt to the raw grain is sometimes dimi nished much below that stated, even as low as only one-tenth o the raw grain.

If the wort is not sufficiently heavy, its specific gravity brought up by adding a strong infusion of ground malt, or bar ley and malt.

The fermentation is generally carried on in open pits, an hurried as much as possible; but of late, some distillers, consi dering that the carbonic acid gas carried off much of the spirit have covered the pits with a flooring, having a trap with a wa ter joint, to prevent the loss of the spirit: this retards the fer

ientation, but the augmentation of the produce, although slight, judged fully equivalent to the loss of time.

The Dutch distillers make their wash much weaker, so that does not weigh more than 18 pounds, by the barrel of 34 gal-ons, more than water, and use a much less quantity of yeast han our distillers. They also attach much importance to the uality of the water: and so highly esteem that of the river Ieuse, that the capital distillers keep sailing lighters in constant mployment to fetch water. And as they are not restrained, ney use for their best corn brandy two-thirds of wheat meal, nd one-third of rye meal. The latter being added, because its ifusion ferments better than that of wheat.

### *West India Rum.*

It is manufactured on the sugar plantations, by taking equal uantities of the skimmings of the sugar pans, of the lees, or eturns, being what is left in the still in a former distillation, nd of water; and to every 10 gallons of this mixture is added gallon of molasses. When this is properly fermented, each 00 gallons affords about 15 gallons of proof rum, strongly fla-oured with the essential oil of the sugar cane, and twice as uch low wines, or weak spirit, to be redistilled.

In Jamaica the rum is sometimes rectified to a strength near-y equal to that of alcohol, and is called *double distilled Ja-naica rum.*

### *Molasses Spirit, or Common Rum.*

This spirit is manufactured in England, by mixing 100 gal-ons of molasses, or treacle, with 300 gallons of water, and 2 allons of yeast. Once or twice a day, the head as it rises is tirred in, to encourage the fermentation; and on the third or ourth day 200 gallons more water are added, and 2 gallons nore yeast. In another four or five days another 2 gallons of east are added, on which the fermentation proceeds with great iolence, and in three or four days the wash will be found no onger to diminish in specific gravity, and of course to be fit or the still.

Each 100 gallons of this wash is computed to yield 22 gal-ons of spirit, 10 gallons of which are equal in strength to 11 f proof spirit.

### *Cider Spirit, or Apple Whiskey,*

Is obtained from wash made of bruised apples, pressed. Each 00 gallons of the fermented juice is computed to yield about 6½ gallons of proof spirit. It is much drank in the United tates.

## *Raisin Spirit,*

Is manufactured for the purpose of giving a brandy flavour t malt spirit. To each cwt. of common raisins are added 34 gal lons of water, and after two or three days some yeast is added When the liquor no longer diminishes in specific gravity, th whole is put into the still and distilled with a quick fire, to brin over as much as possible of the essential oil of the fruit.

One gallon of this spirit will give a sufficient flavour to 16 gallons of malt spirit, to enable it to pass for brandy amongs those unaccustomed to the genuine article.

The strength of spirit is estimated in England, as in France by expressing the quantity of water that must be added to strong spirit to reduce it to a certain arbitrary strength, called proo spirit, or the quantity of water that is contained in excess ir any weak spirit.

The following table shows the specific gravity of spirits o the various strengths as indicated by Clarke's hydrometer, a the temperature of 60 deg. Fahr.

| Under proof. | | | Over proof. | | |
|---|---|---|---|---|---|
| 1 in 2 | — | 9644· | 1 to 20 | — | 9162· |
| 3 | — | 9543· | 15 | — | 9135· |
| 4 | — | 9458· | 10 | — | 9107· |
| 5 | — | 9424· | 9 | — | 9093· |
| 6 | — | 9385· | 8 | — | 9071· |
| 7 | — | 9364· | 7 | — | 9047· |
| 8 | — | 9344· | 6 | — | 9006· |
| 9 | — | 9334· | 5 | — | 8961· |
| 10 | — | 9320· | 4 | — | 8913· |
| 15 | — | 9280· | 3 | — | 8817· |
| 20 | — | 9265· | 2 | — | 8590· |
| Proof spirit | | 9200· | Alcohol | | 8338· |

When spirit is diluted with water, the essential oil it contains frequently renders the liquor cloudy; a little alum in powder mixed with an equal quantity of sub-carbonate of potasse, is usually added to restore the transparency, but the means which has succeeded the best is the solution of white sugar in cold water, mixed afterwards with the spirit, and some white of egg beat up with it. Three or four days are generally sufficient for the complete depuration of the liquid. The sediment which is formed is very considerable, and the liquid easily passes through filters.

Isinglass was used in this operation, and also milk and cream but the latter are never so limpid nor so free of colour as those

which are treated with white of egg. They also have an oily aspect, and do not pass through filtering paper without the greatest difficulty; and milk and cream also injure the taste of the finest spirits and liqueurs.

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The excellence of French brandy depends not only on the material from which it is distilled, but also on the care that is taken to keep it from the contact of any thing that may deteriorate its flavour, by distilling it in well tinned stills, and thus avoiding flavouring it with the taste of copper. The distillers of malt spirit, or potato spirit operating upon an inferior material, have not an equal interest in preventing their spirit from acquiring a foreign flavour; hence they not only employ unlinned copper stills, and worms, but have even attempted to distil in wooden vessels.

Fig. 226 represents a wooden tub, as fitted up by M. Fischer, in Denmark, and used there upon a large scale. *A* is a tub or tun of a very large size, strongly bound with iron hoops, being the body of the still, and to which there is fitted a tin copper neck, head, and worm, of which the first only is shown in the figure. *B* is a square fire room of sheet copper, tinned on the outside, and placed in the middle of the tub; the entrance to which is a square pipe, *c*, which passes beyond the tub, and serves to introduce the fuel: this pipe is closed by the door, *d*. *E* is the ash room, the bottom of the tub being cut out to allow the ashes to fall through. *F* is the copper pipe, tinned like the rest on the outside, that serves as the chimney, and passes through the side of the tub. *G* is a part of the chimney on the outside of the tub, and *h* is another part that passes through the upper part of the tub. The wash is thus heated by a fire made within the tub. All the places where the pipes belonging to the furnace enter the tub must be carefully stopped.

Fig. 227, represents a water bath of a similar construction, devised by M. Fischer for the rectification of the spirit. *A*, is a large tub bound with iron hoops. *B*, is a copper bottom, tinned on the upper surface, and so perfectly adjusted with the sides of the tub, so that the liquor on the upper part may not filter in any manner in the lower part. *C*, is a fire room, like that of the former apparatus. *D*, is the fire room door. *E*, is the chimney, which turns forwards and comes out of the side of the tub at *f*. *G*, is a bent pipe which serves to fill the lower part of the tub with water, and allows a passage to the steam, when the water is heated to that degree which is most favourable for the re-distillation of the spirit with which the upper part of the tub is filled; although towards the end it is necessary to augment the heat.

Fig. 228, represents the condensing apparatus adapted by M. Fischer to these wooden stills, and which was the first example of increasing the size of the worm. *A*, is a large copper cylinder fixed in a barrel, *b*, which is kept filled with cold water by means of a pipe. This cylinder stands out about three inches from each head of the barrel. *C*, is the short pipe at one end of the cylinder, into which the beak of the still head is inserted; and *d*, is the pipe through which the condensed spirit flows into the receiving can.

Fig. 229, represents another apparatus proposed to be substituted in the place of the common worm, as not costing more than one-tenth of the price of the worm, and being much more easily manageable. *A*, *b*, *c*, *d*, is a large open tub filled with water. *E*, *f*, is a tinned copper pipe, which enters into the tub at the hole, *i*, at about half its depth, and is connected at the end with a cock,

*l*. *F, g,* is a pipe which passes perpendicularly to the same height as *i*, the inside of the tub, and being there bent passes out of the side as at *h*. *k,* is a pipe of a very small bore, that joins the two other pipes, *e*, *f*, and *f*, *L, m,* is a glass pipe cemented into the neck of the cock belonging to t pipe, *e, f;* this glass pipe, or barometer tube, is on the outside of the tub, ar supported in its place by stays. All these pipes open into one another.

The end, *e,* of the pipe, *e, f,* being adapted to the beak of the still hea and the cock, *l,* closed, the first portion of liquor that is condensed, fills t several pipes to the level of *g,* after which they run off by the pipe, *g,* The pipe, *i, k,* being intended only as a safety pipe is necessarily of a v small bore, as otherwise the vapours might pass along it and escape with being condensed. The point, *i,* where this pipe is soldered to the pipe, *e,* ought to be a quarter of an inch above the level of the bend, *g,* and the p ir *k,* where it is soldered to the upright pipe, *f; g,* ought also to be a q rter an inch below the level of the bend, *g;* in order that the vapours may su fer other pressure than that of the column of liquor, *g, m.* The use of the coc *l,* is only to empty the pipes, and allow the pipe, *e, f,* to be cleaned. T glass pipe, *l, m,* is merely to show the height of the liquor in the pipe, and th indicate whether the whole apparatus acts properly.

The distilleries in Sweden being a crown manufacture, th commissioners to whom they are intrusted have an opportunit of making extensive experiments on the best construction the apparatus.

Fig. 230, represents the section of the condensing apparatus introduced Mr. Gedda, which consists of two concentric inverted truncated cone within another, at a few inches distance; in which interval or void space, condensation of the vapour is effected by the cold water surrounding the o cone, and filling the inner cone. *A,* is the outer cone, and *b,* the inner co both of which are made of copper, and the surfaces next each other well ned. *C,* is a copper ring which closes the space between the cones at t *D,* is a similar ring to close the space at bottom. These rings are well so le to the cones, and allow a free passage for the water to the inside, *f,* of th ner cones. *E,* is the space between the cones, in which space the vapours condensed. *G,* is the pipe which conveys the vapours from the still he the space, *e,* between the cones; and *h,* is the pipe conveying the conden spirit to the receiving can. *I,* are the three feet which support the conden within the tub, *k,* which ought to rise at least two feet above the con lens and be supplied with cold water from below. The warm water that rises the top, may be drawn off for use as wanted.

The condensers that have been made for the largest stil used in the royal distilleries of Sweden being stills of 600 g lons, and 5 feet in diameter, have the outer cone 34 inch wide at top, and 21 at bottom, and the inner cone 27 inch wide at top, and 19 at bottom, and their height 7 feet; the di tance between the two cones at the upper end is 3½ inches, a at the lower end 1 inch; the cooling surface is about 80 squa feet, and the content of the cooling space about 50 gallons. T price of a condenser of this kind is only half that of a wor fit for a still of the same capacity.

A still of only 2 feet diameter, or 32 gallons, requires onl 10 square feet of cooling surface, and the distance between t cones at the top need only be 1½ inch, and at the bottom ha

Fig. 226

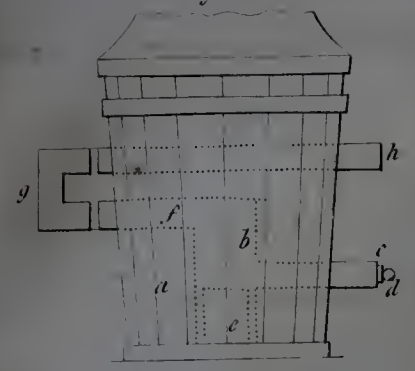



Fig. 227

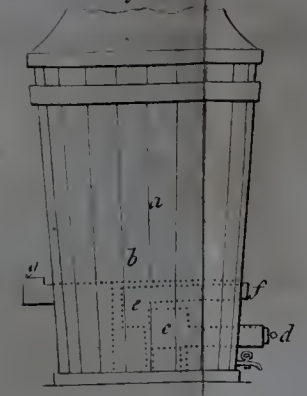



Fig. 230

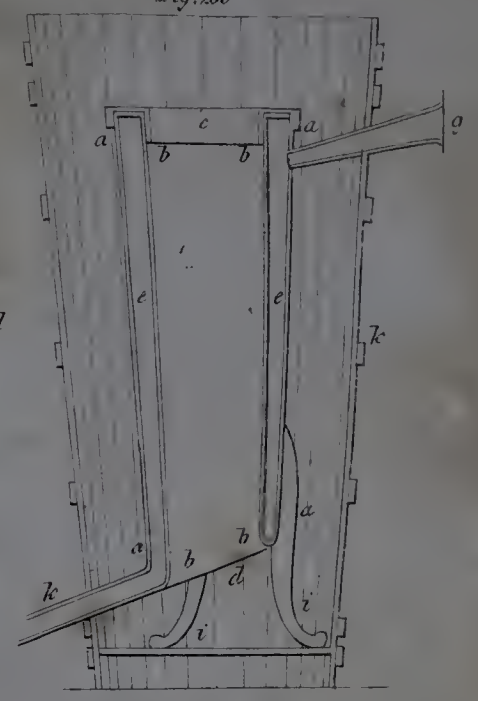
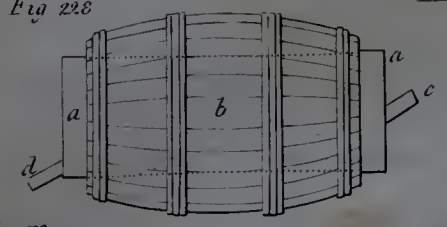



Fig 228



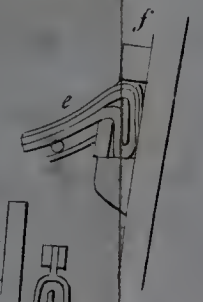




Fig. 233

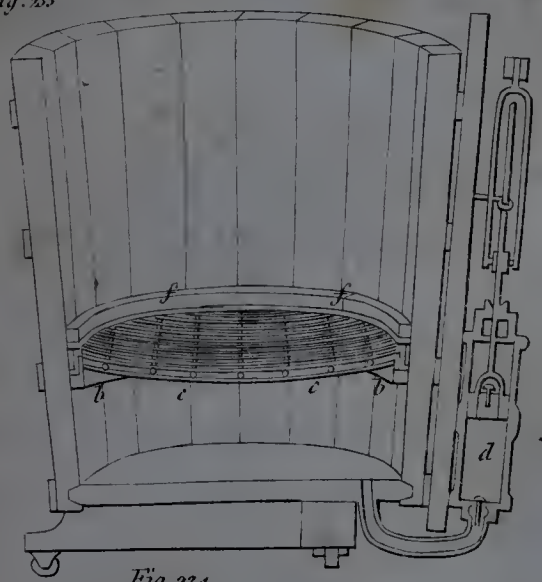



Fig. 229

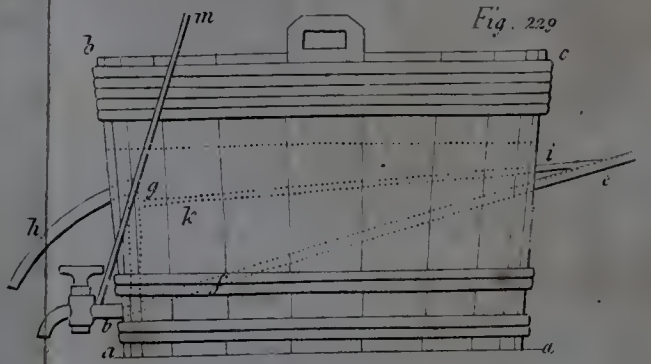



Fig. 234

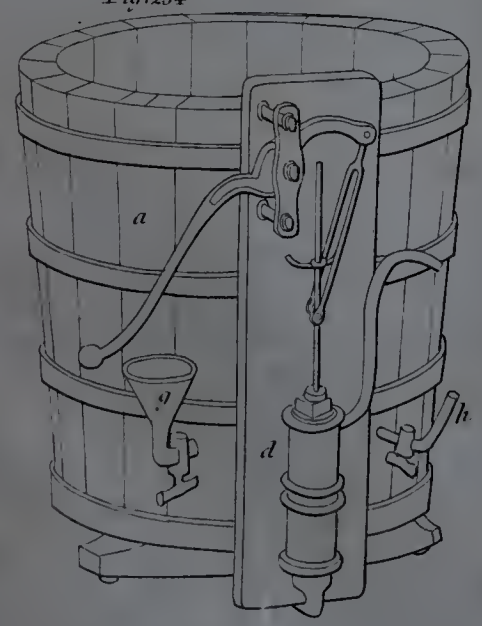



Fig. 231

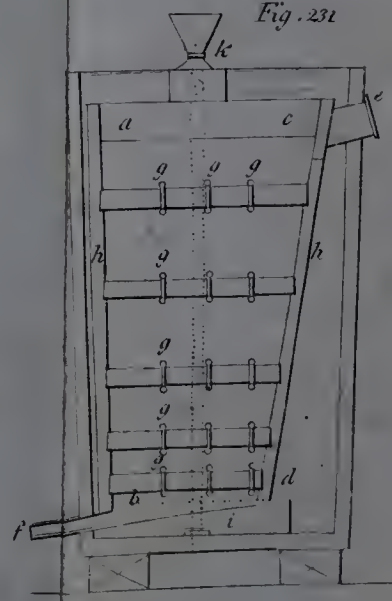



Fig. 232

inch. Some regard must be had to the usual size of the pper plates, that no unnecessary soldering may be neces- ry.

Fig. 231, represents the elevation of a condenser constructed by M. Nor- rg, in the Royal Distillery of Sweden, under his care. This condenser is med of sheets of copper, formed into a chest placed on one of its ends, e height, *a*, *b*, being seven feet, the breadth at top, *a*, *c*, four feet and a half, l at bottom, *b*, *d*, two feet and a half. The sheets of copper at the upper rt are about seven inches apart, for the convenience of receiving the va- urs from the still body through a short pipe, *e*, of six inches bore, but below e entrance of this pipe between the sheets, they are only two inches asun- r. At the bottom of the chest is a pipe, *f*, to convey the condensed spirit o the receiving cans.

As the sheets of copper, of which this condensing chest is formed, ought be rolled very thin, and hence from their weakness might be crushed to- ther by the pressure of the water in the tub in which it is placed, several ws of strong rings, *g*, are soldered to the front and back sheets, through ich bars of wood are thrust, and kept at the proper distance by two stand- ls, *h*, on the sides, which also serve to keep the condenser in its proper po- ion in the tub. The tub, or rather cistern, is adapted to the form of the con- nser, so as to leave about nine inches of water all around it, so that it is in- rnally about nine feet high, five feet wide and only one foot and a half from nt to back. The cold water is conveyed into it by a pipe, *i*, entering at the ttom, and the warm water runs out at the top by a spout. A wide pipe, *k*, soldered in the middle of the top of the condenser, that it may be cleaned, this pipe is at other times kept close by a plug.

This condenser is very similar to the dephlegmator, or al- gene of Prof. Solimanni, but is not placed so advantageously, d it would condense the vapour much more rapidly if it ere placed with its broad surfaces in a horizontal position, in shallow cistern of water about 2 feet deep.

### *Alcohol.*

This is the strongest spirit that can be made, and is usually epared by rectifying the common spirits over potash, muri- e of lime, or quicklime, but since these additions partly ange the nature of the spirit, M. Hermbstadt observes, eir utility in distillation is not such as has generally been pposed. M. Duebac has tried a variety of substances, the incipal of which were, burnt stucco, calcined Glauber's salts, ommon salt heated, and potters' clay, of which the last ap- eared best to answer the purpose. To 12 ounces of clay, ell washed, sifted and strongly dried, M. Duebac applied 32 unces of spirit of wine, at 39 deg. Baumé, or sp. gr. 0·832, hich on being distilled yielded alcohol of 42 deg. Baumé, r the spec. grav. 0·820; and which, on being re-distilled with otters' clay, became no lighter, whence M. Duebac looked pon it to be pure alcohol, whereas, that obtained by the appli- tion of potash and muriate of lime may be brought to 50 eg. Baumé, or the spec. grav. 0·782; but this seems owing to

the formation of ether. M. Hermbstadt asserts, that by si ply distilling brandy six times without having recours any substance for the purpose of divesting it of its aquec parts, he has obtained alcohol, spec. grav. of 0·800, or 46 d Baumé, of course it was lighter than that which M. Duel purified by means of potters' clay.

### ETHEREAL OILS.

These are distinguished from other oils by their being d tillable with little or no alteration by a heat not exceeding tl of boiling water, or at least, that of boiling sea water.

They are most generally obtained by distilling strong scented vegetables with water; but a few are obtained by oth processes; some are collected in the cells of plants, and requi only pressure, or the cell to be laid open by a hatchet, to flo out, as the essence of lemons, laurel oil, Sumatra camphi and liquid camphire.

### *Essential Oils of Plants.*

The plants from which ethereal oils are to be distilled sho be collected at the time when their scent is most powerful, a in most instances it is preferable to dry them previous to d tillation, to get rid of some of the acid juices of the sap of plant, which, by enabling the water with which they are d tilled to dissolve more of the oil than it otherwise wou would diminish the produce. This drying is still ordered the Pharmacopœia to be made in the shade, notwithstandi the sarcastic remarks of Culpeper in his notes to the first e tion of that work. He directs the physicians of the Colle to inquire of the farmers whether their hay is not best got in the hottest sunshine. The frequent turning of plants dryi in the sun is necessary, and it was only to avoid exposi themselves to the sun that the ladies, who were formerly t distillers of these oils, were directed to dry them in the sha When sunshine is not procurable, the plants should be dried a kiln as quick as possible.

Woods must be reduced to shavings, barks and simi substances reduced to a gross powder; and these, in ge ral, require to be soaked for some days before they are d tilled, in water acuated with salt, or even a little spirit salt.

The copper still should be well tinned, that the oil m not be tinged by dissolving any of the copper in its passa The body no bigger than will hold the substance and t water, that the oil may have less height to rise; and for t

ne reason the moor's head is preferable to the swan-neck ca-
al: the moor's head should be covered with a flannel cap
pt moist, with a drip of water from a cask or jar placed
ove it.

No more water should be added than is necessary to bring
er the oil, and prevent the matter from burning to the still:
nce, the goods should first be floated with water, and then
re added by weight or measure. In goods that yield their
casily, about six times their weight is sufficient; but in
hers, which yield their oil with difficulty, as the woods, ten
nes their weight must be added.

The distillation is continued with a quick fire, until the quan-
y of water that was added is come over; and if the last por-
ns bring over any oil with them, the fire is slackened, and
distilled water returned into the still, and brought over
ain: this is sometimes necessary to be repeated a second
ne.

The common spiral worm is by no means proper for distilling
s, unless in those manufactories where only one oil is made,
account of the difficulty of cleaning it, and the danger of
s mixing the scents of two or more oils together. The
aight pipes, shown in fig. 8, are preferable, and still more
encased single straight pipe of fig. 7.

In distilling liquid oils, the condensing worm or pipes are
pt as cool as possible; but there are some oils, as aniseed oil,
hich are apt to congeal in the condensing apparatus; and hence,
is must be kept so warm as to prevent its congelation.

The quantity of oil which comes over being very small in
mparison with that of the water, the spirit receiver of fig.
9, is most commonly used, which allows the water to pass
into another vessel, and retains the oil whether it floats on
e water or sinks in it; or the Italian receiver of fig. 7.

The water which has been used in a preceding distillation
ay, in general, be advantageously used in a second operation
th fresh goods, and sometimes a third; but by frequent co-
bation the water becomes acid, and takes up the oil, thus
minishing its produce.

Roses must be distilled with their green flower cups, and
re open by the nails, as the liquid or scented oil is lodged in
cell at the claw of each petal. By adding a little spirit of
lt to the water, and digesting for a few days, the produce was
ubled.

Some of these oils, as those of aniseeds, chamomile flowers, caraway seeds,
ssia buds as a substitute for oil of cinnamon, cinnamon, cloves, dill, juniper
rries, mint, nutmegs, pennyroyal, peppermint, rue, sassafras, savine, and

wormword, are used in medicine as carminatives and stimulants. Others, those of aniseeds, caraway seeds, cassia buds, cinnamon, cloves, juniper b ries, and pepper, in compounding the cordial waters of the spirit dealers. third class, as those of balm, citron flowers, called *essence de cedrat*, laven flowers, broad leaved lavender, called *true oil of spike*, orange flowers, call *neroli*, roses, rosemary, sanders, or sandal wood, and thyme, called *huile de ta* are used to scent spirits of wine, and form what are called waters for the toil as eau de Cologne, Hungary water, and the like, and which are used by the dies of the upper class of society as cordials. Others, as those of balm, ca mus aromaticus, chamomile flowers, caraway seeds, hysop, lavender flowe marjoram, milfoil, parsley, rosemary, sage, sassafras, and thyme, to sce soaps.

## *Essential Oil of Bitter Almonds.*

This oil requires particular treatment, 32 pounds of bitt almonds being taken and pressed to get out their fixed oil, t cake is to be ground to a coarse powder, and distilled with wine gallons of water, until the whole is come over; abo three-fourths of an ounce of oil will swim on the water, and to be taken off. As much salt as the water will dissolve is th added to it, and about a gallon distilled off, which will bri with it nearly 4½ ounces more of oil.

The distillation of this oil ought to be made in the op air. In a common laboratory the operator, and indeed all the house, will probably be disabled by the head-ache for se ral days. As the operator may faint during the process, watch must be kept on him.

This oil is a poison of the quickest action, but being diluted with seven ti the quantity of spirit of wine, it is used under the name of *essence of bitter monds* by the confectioners and makers of liquors, to communicate the fla of peach kernels.

## *Oil of Turpentine.*

This is also frequently called spirit of turpentine. It is m nufactured in large quantities, by distilling turpentine in iron still, with a condensing apparatus, until the drops of begin to grow coloured.

One cwt. of turpentine yields from 12 to 20 pounds of o the slower it is distilled, the greater is its yield in oil.

Oil of turpentine is used principally to add to oil paints of light colours cause them to dry quickly; it is also used in the composition of varnishes; to take spots of grease and paint out of clothes, which it performs by disso ing them, and then being volatilized itself by the application of a hot iron carries the grease along with it.

When turpentine is dear the oil is distilled from frankincense, but it is ve greasy, and far inferior to the real oil.

For medical purposes, the turpentine is either distilled with water, as oth essential oils, or rectified with it: but it absorbs water in this process, and comes useless to painters.

## *Camphire.*

The rough camphire, brought from the East Indies, requires be refined by sublimation, on account of the foulness that acquires during the rude distillation of it, as practised by e country people of those parts, who only throw branches of e camphire laurel into water, boiling in a pot, and receive the blimed camphire in another pot, stuffed with straw ropes, d placed with its mouth downwards on the boiler: the cam- ire adheres, in small grains, to the straw ropes, from which is afterwards shaken.

Each cwt. of rough camphire is mixed with 2 pounds of icklime, in powder, and the whole charged into flattened lt heads, which are placed in a sand heat, and the sublima- on performed in a very gentle heat. This operation requires nsiderable skill to form a solid nearly transparent cake of mphire, that being the marketable quality.

The bolt heads are placed on the sand, and that gradually ised round them, so that by the time the camphire is melted e sand reaches to the surface of the melted camphire: the hole bulk of the bolt head is then covered with the hot sand melt the camphire that has sublimed during the melting, and use it to run down. The upper part of the bolt head is then adually uncovered as the camphire sublimes. When the sub- mation is finished the bolt head is cooled and broke to extract e cake of refined camphire; the sublimation of 2lbs. ½ of mphire lasts about seven or eight hours.

As a skilful operator has more command over a naked fire an a sand bath, and this operation requires great attention to e heat, some chemists prefer coating the lower half of the lt heads with a clay lute, and hanging them in a pot furnace, ith a separate fire to each; the management of the sand with hich the upper part of the bolt head is covered is the same in the former mode.

Another method has been proposed to prevent the expense breaking the bolt heads, which is, to distil the camphire in retort, or an iron pot with a stone ware head, with a quick re that it may not settle in the arch or neck of the distilling essels, but be forced over in a liquid form into the receiver, hich is a large globe of tinned copper. The lower half of is globe is a separate piece luted to the upper half; and when e distillation is finished and the vessels cooled, this lower he- isphere is separated, and held over a fire to melt the surface the camphire next it, and being then turned over the cake of mphire falls out.

Camphire is principally used in medicine, and in the composition of f works; its volatility prevents its being used in varnishes, where its whiten would be very advantageous.

## *Ether.*

Ether, as is learned from Raymund Lully and the Hon. Mr. Boyle, was ( ginally prepared by digesting three parts of good spirituous wine with on p of oil of vitriol for six weeks, and then distilling the mixture with a gentle he the ether thus obtained was then called *philosophical spirit of wine.*

At present ether is made from spirit of wine, and witho previous digestion. Highly rectified spirit of wine being p into a glass retort, there is added, by degrees, an equal weig of oil of vitriol; the retort being shaken on each addition the acid and placed on warm sand, so that whatever is co densed in the neck may run back into the bowl of the reto the mouth being stopped with a cork. When all the acid introduced, the retort is placed in the proper position for d tillation in a pot of warm sand, and there is luted to it with expedition a stoppered and quilled receiver, a receiving bot to the quill, and a bent pipe to the stopper hole, to convey t vapours into another bottle: all prepared beforehand.

The mixture in the retort is brought as quickly as possi to boil gently, and kept at that heat until white vapours be to appear, which generally happens when a quantity of et has been distilled which is equal to two-thirds of the spirit wine. The receiving bottles are then unluted, removed, stantly stopped with corks prepared for that purpose, and fre bottles applied to the receiver. The distillation is then co tinued with an increased heat until the mixture grows bla and begins to rise in froth, when the fire is withdrawn and t fire room filled with cold wet bricks.

The liquor distilled in the first part of the operation has ounce of fresh slaked lime added to each pound of fluid, a the whole is shaken together, and being decanted is mixed wi an equal quantity of water, shaken together, again decante muriate of lime, or chloride of calcium, added to absorb t water, and the whole distilled in a smaller apparatus similar that used at first.

Hellot observes in his papers on ether, in the Mem. Aca Sciences, that in endeavouring to prevent the formation of t ethereal oil of wine, or as it was then called, the sweet spirit vitriol, he found that 6 ounces of well dried and powdered po ters' clay being put into a retort, 16 ounces of spirit of wi poured in also, and then 8 ounces of oil of vitriol, and the who digested for three or four days, the mixture acquired no sens ble colour. On submitting this mixture to distillation witho taking any great care as to the heat, but keeping the liqu

iling until the whole was brought to dryness, it yielded only few drops of undecomposed spirit of wine, and the whole reaining distilled liquor was the vinous acid spirit containing her, without any production of oil of wine, sulphurous acid quor, or black scum.

The great volatility of ether requires extraordinary precautions to preserve it is best kept in a phial closed with a fresh sound cork every time it is ened and tied down. If it is to be kept for any time, a little quicksilver is be put into the phial, which after being corked, is kept with the mouth wnwards in a jar of water.

The extreme ease with which ether and its vapour catches fire is also ano-er source of trouble to the chemist, and almost precludes its being poured t in a room or laboratory where there is either fire or candle. Should a eam of fired ether run along a floor, water is useless in extinguishing it, as rises to the surface, and takes fire again; wet sand or ashes is the only reme-, and hence, one of these should always be in readiness in distilling ether.

Ether is used in medicine; and in gilding steel, as when poured upon solu-n of gold in aqua regia, it takes up the gold from the acid: it is also used in me varnishes, but its great price is against its employment.

## *Ethereal Oil of Wine.*

This is a secondary product, obtained by continuing the distil-tion after the acid vinous spirit containing the ether has come er.

In the process for ether, as already given, the ethereal oil mes over along with a sulphurous acid liquor in the second t of receiving bottles, mostly of a yellow colour, some of it ating on the acid liquor, and some sunk at the bottom.

Some chemists, instead of increasing the heat when the se-nd set of receiving bottles are adapted to the receiver, dimi-ish the heat, and when the rising of the black froth takes lace they remove the retort from the fire, and add to the liquor ft in it some water to separate the oil, which they afterwards hake along with lime water to remove any acid it might retain.

Mr. Phillips denies the existence of ethereal oil of wine; hat he prepared was ether mixed with about five-thirty-se-nd parts of sulphurous acid; what he bought at different shops n London was yellow ether without any sulphurous acid.

Hellot found that the sensible qualities of ethereal oil of wine iffered according to the proportion of oil of vitriol added to he spirit of wine in the first admixture. When one part of il of vitriol is added to three, four, five, or six parts of spirit f wine, the ethereal oil was white, and always floated upon he acid liquor; with two parts of spirit the oil was yellow, and ost commonly under the acid liquor; with equal parts of spirit f wine and oil of vitriol the ethereal oil was greenish, and con-tantly under the acid.

Ethereal oil of wine is only used in medicine, and but seldom.

### *Coal Nafta.*

This is obtained in distilling coal tar, the distillation bei begun with a very gentle heat, and the produce removed soon as the oil comes over of a reddish colour.

If a still finer article is desired, the white nafta is withdra as soon as the oil comes over of a yellowish tint, and the y low nafta is then collected separately.

Coal nafta is used in preparing varnishes; and has also been used in lam in which last use its aptitude to take fire, which is nearly equal to that of eth requires peculiar precautions to be taken.

### *Oil-gas Oil.*

This is deposited in the vessels in which oil gas is compressed to one-t tieth of its bulk, to be afterwards transferred to portable gas lamps.

One thousand cubic feet of oil gas by compression, produce nearly a gal of this oil.

It is used to dissolve Indian rubber, and is the best solvent yet known that purpose. As it is so far more volatile than oil of turpentine, it would swer for making varnishes which are required to dry very quick.

### *Pyroligneous Ether,*

Is obtained copiously in the distillation of wood; it bu with a peculiar smell, but is an excellent fuel for lamps, much cheaper than spirit of wine.

## DISTILLED OILS.

These differ from the ethereal oils by being less volatile, thus by requiring a greater heat to raise them, they have quired a dark colour, and a burnt or smoky odour, whence th have been called empyreumatic oils.

### *Tar.*

This is obtained as a secondary product in making charc of resinous woods; namely, of the pine and fir trees.

The general process is to mark out a circular tar hearth the forest, of about 30 feet in diameter, which is paved wit slope towards its centre, or at least formed of a thick bed well-rammed clay. From near the centre a trough, or cover gutter is formed, which is frequently only a tree split, hollow and then joined together with clay, with which it is also coat to defend it from the fire. This trough ends in a cistern sunk the ground to receive the tar as it flows from the trough.

A pole 15 or 18 feet long being stuck upright in the cen of the hearth, the billets, or fagots of resinous wood are pil round it in a bed of about 20 feet in diameter. Upon thi

l of less diameter is made, and so on decreasing gradually to
m a conical pile; which is covered with fresh cut turfs,
ving a few openings round the pile on a level with the ground.
e whole being left for a day or two to settle, the pole in the
ddle is withdrawn and the pile lighted at the bottom holes.
hen the pile is well lighted the holes are stopped, and should
fire appear by any cracks in the covering, fresh turfs are
d to the place. The third day the end of the gutter next the
tern is opened, which had hitherto been stopped, and the tar
eady made, permitted to run out. This opening is then closed
ain, and only opened two or three times a day during the re-
inder of the process.

The tar thus obtained generally requires to be heated in large
n pots, to drive away the water and pyroligneous acid that
s out along with it, and cannot be separated by ladling, and
o to allow the sand and other impurities which the tar con-
cts in this rude process to settle, and be thus separated.

In Sweden and Norway, where the Scotch fir, or pinus syl-
stris, is a regular crop, tar furnaces are built of brick work,
rfectly similar to these piles, and hence their tar being clean,
of a superior value in the market.

In North Carolina, from whence the greater part of Ameri-
n tar is brought, the pitch pine, pinus palustris, is used; and
ose trees which have fallen down in the woods, and the sap
ood rotted off, are preferred, under the name of light wood,
called because it takes fire very readily. A pile of this pitch
ne, 20 feet in diameter and 14 feet high, is computed to pro-
ce 200 barrels of tar.

### *Green Tar.*

This is made in the same manner as common tar, from the wood of those
es which have done yielding turpentine by incision.

All the French, or Bordeaux tar, is made in this manner from the sea-pine,
*nus maritima*, and much of the American.

Tar is used as a cheap varnish for wood work; as also as a raw material to
ake pitch.

### *Pyroligneous Tar.*

This is a secondary product collected in distilling wood which is not of a re-
nous nature, to obtain pyroligneous acid, or charcoal, for making gunpowder,
described in p. 289.

It may be used for the same purposes as tar: with which, however, it will
ot unite.

### *Coal Tar.*

This has been prepared ever since 1740 in brick furnaces, si-
ilar to those used for preparing the common tar. These fur-
aces yielded a barrel of tar from 2 to 4 tons $\frac{1}{2}$ of the small coal,
which is scarcely saleable and usually wasted.

Since the use of coal gas for illumination, this tar has be secondary product, as described in the article on coal gas may be used for the same purposes as common tar; but as s prejudices exist against its use, it is mostly employed for i mination.

### *Oil of Bones,*

Obtained as a secondary product in distilling bones, for production of hartshorn or bone spirit, and ivory black.

On account of its fetid smell, it is only burnt for lamp-bla and in Gallicia for miners' lamps, as it gives a very brill light, and will burn in air from 100 parts of which only 18 p ·8 of oxygen can be obtained.

Now that flock paper is out of fashion for rooms, the Fre add chopped woollen cloth, and refuse wool to the bones.

### *Oil of Birch Bark.*

The Russians obtain this oil by filling a large earthen with the thin whitish paper-like external bark of the birch t carefully separated from the coarse bark, closing the mout this pot with a wooden bung, pierced with several holes: then turning it over and luting it with clay to the mouth o other of the same size. A hole being dug in the ground, empty pot is buried in it, and a fire is lighted round and c the pot containing the bark, which is continued for some ho according to the size of the pot. When the apparatus is co and unluted, the lower pot contains the brown oil, mixed w pyroligneous tar, and swimming on an acid liquid.

In some places iron pots are used for this purpose, and bark is hindered from falling into the lower pot by a plat iron, pierced with holes; 100 pounds of bark yield about 6 oil.

The waste of fuel in this process may be avoided by plac the pots in the side chamber of a reverberatory furnace, fill the chamber a little above the joining of the pots with sand, then proceeding to distillation.

This oil is used in Russia for currying leather, to whic gives a peculiar odour, and a power of resisting moisture, far yond any other dressing. Its use seems to have arisen from serving that the thin paper-like leaves of birch bark, remai after the coarser part of the bark, and the timber of fallen tr had rotted. The oil appears to owe this quality to a resin, whi by this mode of distilling per descensum, is allowed to esc in a great measure from the action of the fire, and drop into lower pot.

ther barks, as those of the oak, willow, poplar, alder, as also poplar buds, and savine, have been tried, but the produce from them was only a stink- oil. Birch wood yields only a stinking oil totally unlike the oil of the ex- al bark. Cork yielded an oil approaching in some degree to that of birch k.

### *Oil of Benzoin.*

his oil is distilled from the residuum left in making flowers of benzoin by limation. The distillation is effected in a retort, or in an iron pot with a e ware head.
is used for currying leather in imitation of the Russian leather.

### FIXT OILS AND ROSINS.

The distinctive marks of these oils is, that they cannot be tilled without becoming an entirely different thing.

A great proportion of the fixt oils in use are not obtained by emical means, but by mechanical pressure: the construction oil mills for this purpose is excellently shown in Nicholson's erative Mechanic. To this class belong the various qualities olive and rape oils, as also nut oil, linseed oil, and many ers.

### *Pitch.*

Two methods are in general use for making pitch; namely, her simply boiling the tar in large iron pots, or setting it on and letting it burn, until by dipping a stick into it the pitch pears to have acquired the proper consistence.

Two barrels of the best tar, or 2 barrels ½ of green tar are mputed to make one barrel of pitch.

Pitch is used as a coarse varnish for ships' bottoms, also to close the joints carpenters' and coopers' works, to enable them to retain water.

### *Brown Rosin.*

This is the residuum left in the still after turpentine has been stilled without water for its oil; and which is run or ladled t of the still into casks cut in half for sale.

Its colour is more or less dark, sometimes approaching near- to black, according to the degree that the distillation has been shed.

It is used as the base of many common varnishes and cements; also to sprin- on the surface of metals that are to be joined with another metal, in order promote their union. It is also made with tallow into a soap.
When melted with a little vinegar to render it clammy, it is used by violin yers to rub their bows.

### *Yellow Rosin.*

This is made by ladling out the brown rosin from the still into

a vessel of hot water; a violent effervescence takes place, and the rosin absorbs one-eighth of its weight of water.

It is used for the same purposes as brown rosin, but is more hard, and therefore less adapted for cement; its light colour, however, is sometimes advantageous.

### *Spirit Varnishes.*

Almost every workman that uses varnish has his own receipt for making it. These receipts are mostly remarkable for the number of ingredients, some of which are of scarcely any use, and others absolutely hurtful to the wished for effect.

Brown rosin, gum sandarac, mastic, shell lac, seed lac, dissolved in strong spirit of wine, generally form the basis; Venice or common turpentine is added to prevent the varnish from cracking as it dries; camphire, anime, benzoin, alemi, are occasionally introduced; also gamboge, turmeric, dragons' blood, saffron, and lamp black, as colouring ingredients.

The common varnish is made by dissolving 4 ounces of sandarac, and 6 ounces of Venice turpentine, in a pint of spirit of wine.

A harder varnish is made by dissolving 2 ounces of mastic, 1 ounce ½ of sandarac, and 1 ounce ½ of Venice turpentine in a pint of spirit of wine.

A very hard varnish, much used of late by the name of *French polish for furniture*, is made by dissolving 3 ounces of shell lac, with 1 ounce each of mastic and shell lac in 2 pints ½ of spirit of wine in a gentle heat, making up the loss by evaporation by adding more spirit at the end of the process.

The plain solution of either mastic or sandarac in the proportion of about three ounces to a pint of spirit of wine makes a very good varnish.

Yellow varnishes are used by the name of *lacquers* to give a golden colour to metals, wood, or leather: the following is, perhaps, that most used: colour a pint of spirit of wine with three quarters of an ounce of turmeric, and fifteen grains of hay saffron; filter and dissolve in it two ounces each sandarac and gamboge, one ounce each dragons' blood and seed lac, and three-quarters of an ounce of gamboge.

Black varnish is made for sale by dissolving half a pound of sandarac, and a quarter of a pound of yellow rosin, in half a gallon of spirit of wine, and then adding two ounces of lamp black to colour it. But workmen generally make it by dissolving black sealing wax in spirit of wine.

The making of varnish from copal is a matter of difficulty, as copal is not soluble itself in its raw state in the spirit. The method is to add camphire to a pint of highly rectified spirit of

ne until it ceases to be dissolved, and to pour this charged rit upon four ounces of copal, keeping up such a heat that bubbles may be counted. When cold pour off the varnish, l if all the copal be not dissolved, add more spirit impregted with camphire. Another method is to heat the copal and it drop as it melts into water; a kind of oil separates from it, d it becomes soluble in ardent spirit, and still more so if the lting is repeated.

### *Oil Varnishes.*

In these varnishes, as in spirit varnishes, almost every operahas his own receipts. So that it is only the general outlines their composition that can be given.

*Drying oil, or boiled oil,* is one of the most common varnishes, and is used to x with colours, partly as a vehicle, and partly to cause them to dry quickly. Inseed, or nut oil, is boiled with a very small proportion of dried white lead, harge, dry saccharum saturni, or white vitriol, generally an ounce either of ch article, or a proportionate quantity of several to the heat of oil. Sometes the oils are merely left to stand upon litharge for a long time.

*Oil varnishes for covering pictures* are not much used, as they are not easily moved. They are mostly composed of gum mastic, various proportions of pal varnish, Canada balsam, and thinned with oil of turpentine.

*The varnish used for bright armour and weapons,* by our ancestors, was, 3 lbs. brown rosin, 2 lbs. of turpentine, dissolved in 10 pints of boiled linseed oil.

*The engravers' varnish* for covering copper plates, and preventing the acid d in etching from corroding the places wished to be left blank, varies much its composition. The hard varnish used with Callot's aqua fortis is merely stic dissolved by boiling in an equal weight of drying linseed oil. Le Boffe's t varnish, which is that generally used in England, is made by heating 2 oz. white wax, and adding to it, by degrees, first, 1 oz. of mastic in fine powder, d then 1 oz. of asphaltum, keeping it on the fire until all is completely disved. Mr. Lowry used 4 oz. of asphaltum, 2 oz. of Burgundy pitch, and 2 . of white wax, melted together. The varnish called *the soft ground* is prered by adding some veal suet to the soft varnish already described.

The French artists use gum benzoin instead of asphaltum, aking their soft varnish of eight ounces of linseed oil, in which dissolved one ounce of gum benzoin and white wax, and keep on the fire till one-third is boiled away. For their hard varsh they add more white wax, so as to enable it to be made into solid ball.

The superior clearness of copal to either shell lac or amber, ves it an advantage in varnishes and japan work; but the difculty of dissolving it, either in oils or spirits, is very great. y grinding it with camphire, or by first melting it and letting drop into water, it becomes more soluble.

The Japanners' copal varnish is made by melting 4 lbs. of copal in a glass maas, until the vapour condensed upon any cold substance, drops quietly to the ttom; then adding first a pint of boiling linseed oil, and afterwards about its vn weight of oil of turpentine.

Le Blond added 1 oz. of copal to 4 lbs. of balsam of capivi, expo[illegible] sun until dissolved; then added another ounce, and so on until he got in a [illegible] of copal; he then added Scio turpentine as he thought necessary, and [illegible] for varnishing prints.

Sheldrake prepared his copal varnish for varnishing pictures, by mi[illegible] pint of oil of turpentine, with 2 oz. of aqua ammonia, and dissolving 2 o[illegible] copal in this mixed liquor, by a heat regulated so that the bubbles as t[illegible] may be counted. For mixing up with painters' colours, he boils 2 oz. [illegible] russ, with a pint of nut or poppy oil; and when the ceruss is dissolve[illegible], a pint of his copal varnish, previously warmed, and stirs it until the oil of pentine is evaporated. This gives the colours more brightness than c[illegible] drying oil, but less than common varnish. It loses its drying quality in t therefore only so much as is sufficient for a month or six weeks' consu[illegible] should be made at once.

## *Boiled Oil.*

As the oil used in oil painting is required to dry very fast, oil of linseed and walnuts have their own natural drying qu ties augmented by being boiled slightly with white lead, lead, sugar of lead, litharge, German, or white vitriol; us about four ounces of any of them to the gallon of oil. pure sulphate of zinc made in England has not the same dry quality as the common white vitriol imported from Germa

The oil for painting on velvet is also made drying by bo Very clear linseed oil one pint, add sal ammoniac and sal nelle, of each twenty grains, boil for two hours, then put piece of bread soaked in oil of vitriol, and three large o cut into pieces, and continue the boiling for another hour, st through a coarse cloth.

## *Fired Oil, or Printers' Varnish.*

If the colouring material of printers' ink were mixed up v raw linseed oil or nut oil, it would not give so clear an imp sion, the small letters would soon fill up, the impression of large letters would be surrounded by a greasy border, and as ink would be long in drying, the impression would be extrem liable to accidental smears, and the book could not be bound months after it was printed, without marking the opposite pa. All these inconveniences are prevented by heating the oil in iron pot, and setting it on fire, until on dipping a wooden k into it the operator judges, by the ropiness that is acquired the oil, that the varnish, as it is now called, is properly ma The pot is then covered to extinguish the flame, and the fire un it withdrawn.

## *Japan Work.*

The natives of Japan and China have a decided advantage manufacturing fine japan work in regard to their material. Th use the turpentine obtained by incision from the terminalia v

, which becomes a hard black rosin by exposure to the air. hasten this effect it is put into very shallow bowls, and con- ually stirred with an iron rod during twenty-four hours, so to expose every part to the action of the air. This makes it cker than before, and of a fine black colour.

When this lac is laid on the work and dried, it is polished, l the polished surface is ornamented by gilding or painting, ich is secured by an external coat of varnish, made of oil and pentine, boiled to a proper consistence. For coarse work p black is added.

The japanning of Europeans is differently performed; but the rk bears a near resemblance to that of the Japanese when ished: it is applied to wood, papier-maché, leather, and iron, tinned iron. When the articles are of that nature that they ll not bear heating in a stove to dry and harden the japan, y must be done with lac, reduced to a fluid state, by dis- ving it in some essential oil, and this varnish being spread the work, the oil will evaporate, and leave a hard superficial t of japan. The varnish may be mixed with the requisite lours, or the colours may be painted upon the surface of the rnish between the successive coats which are applied; and in latter case, admit of painting according to a design.

For such goods as will admit of sufficient heat in a stove, a re economical method is pursued, the principal coats of japan ing made of boiled linseed oil with proper colouring matters. hese are dried and hardened in the stove, and the painting or ding is laid on; a thin lac varnish is lastly applied to give the ternal surface.

*Japanning with Lac.* This is principally used for orna- enting wood, leather, and paper, but the latter can be japanned heat like the metals.

Varnishes which are to form the grounds or surfaces on which e painting or gilding is to be laid, are thus produced.—Dis- lve two ounces of coarse seed lac, and two ounces of rosin, in e pint of rectified spirit of wine. This varnish must be laid in a warm place; and the work will be better done if the bstance to be japanned can be warmed also. Two or three ats of this coarse varnish are applied, preparatory to laying e grounds.

For a *white ground.* Grind flake white with one-sixth of s weight of starch, temper it with mastic varnish, prepared by ssolving mastic in spirits of turpentine, by a gentle heat in a arm bath; or the colour may be compounded with gum anime, duced to powder, and ground first with turpentine, and then ound with the colour, adding as much of the mastic varnish is necessary to make it work with the pencil.

When this white japan is laid on, the external varnish which is applied upon it, after the painting or ornaments are finished, must be of the most transparent nature, that it may not injure the whiteness of the colour. Take two ounces of chosen gum and three ounces of gum anime, reduce them to a gross powder and dissolve them in two pints of spirit of wine; five or six coats of this varnish must be laid on over the white colour. The seed lac will give a slight tinge to the colour, but the hardest varnish cannot be made without it. When hardness is not so essential a less proportion of seed lac may be used; and to take away the brittleness of the gum anime, a small quantity of crude turpentine may be added. Another varnish, either for mixing up with the white colours or for covering them when laid on, is made of gum anime dissolved in old nut or poppy oil, by gently heating the oil and putting into it as much of the gum as it will take up. This varnish must be diluted with oil of turpentine for use, it will not bear polishing, and therefore must be applied very carefully that it may lay smooth.

For *blue japan grounds*, use a bright Prussian blue, or smalt or verditer glazed over by Prussian blue; the colours are to be mixed with shell lac varnish, and brought to a polishing state by five or six coats of seed lac varnish. If the blue ground is bright and the shell lac varnish is laid on, it will give a green hue owing to its own yellow colour.

For *red japan grounds* vermilion may be used to produce a scarlet ground, but it has a glaring effect when used alone: this is corrected by glazing it over with carmine or fine lake, or even with rose pink. For a very bright crimson Indian lake may be used; the lake may be dissolved in the spirit of which the varnish is composed, and a coat of this being laid on, the shell lac varnish may be used to produce the external surface, as it will very well transmit the tinge of the Indian lake.

For *yellow japan grounds*, bright yellow, king's yellow, or turpeth mineral should be employed, either alone or mixed with fine Dutch pink. The effect may be heightened by dissolving powdered turmeric root in the alcohol, which is used for making the external varnish. Dutch pink alone, if of the best quality, will make a good yellow ground.

For *green japan grounds*, king's yellow, or turpeth mineral with bright Prussian blue, may be mixed to make a green. A common kind may be made of verdigris, mixed with either of the above yellows, or with Dutch pink. For a very bright green, distilled verdigris should be employed; and to heighten the effect, the colour should be laid on a ground of leaf gold, which renders it very brilliant.

For *orange japan grounds*, mix vermilion or red lead with

g's yellow or Dutch pink, or orange lake used alone is a fine
our.

For *purple japan grounds*, a mixture of lake and Prussian
e may be used, or vermilion or Prussian for a coarser purple.

For *a black japan ground*. Ivory black and lamp black
the proper materials. They should be laid on with shell
varnish, but the external varnish may be of seed lac, as the
ge of it can do no injury.

For *gold grounds*. Gold leaf may be laid on over the whole
face. Or the imitative gold or silver powder may be used
th size.

When the desired ground is obtained, the ornamental paint-
g is next performed. The colours for painting are mixed up
th varnish of shell or seed lac, dissolved in spirit of wine, or
herwise, by mastic varnish, dissolved in oil of turpentine; to
hich gum anime may be added, as before directed, for mixing
the colours of the white ground, and which applies to all the
her grounds. The pencils must be moistened either with the
irit of wine or oil of turpentine, so as to make the colours
rk. In some very nice works, the colours may be tempered
oil, for the more free use of the pencil, and to obtain greater
spatch. The oil should, previously, have one-fourth part of
weight of gum anime dissolved in it, or gum sandarac or
astic. When this oil is used, it should be diluted with spirit
turpentine, that the colours may lie more even and thin.

When the painting is to be on a ground of gold, water colours
ay be used for the ornamental painting. They are prepared
ith isinglass size, corrected with honey or sugar candy.

*External Varnish.* The hardest varnish is made of seed
c, but has a yellow tinge. To make this, wash the seed lac
water, dry it, powder it coarsely, then put three ounces of it
to a bottle, with a pint of rectified spirit of wine, and keep it
a warm place, until as much of the lac is dissolved as can be;
he varnish is then to be poured off. This varnish must be laid
n in a dry warm place, and the work previously made perfect-
y dry.

When the outer varnish has been as often repeated as is ne-
essary, the work is polished with fine powdered pumice stone,
r rotten stone; and when a good surface is thus obtained, it is
nished by rubbing it with the hand alone, or with butter or
il.

About the middle of the last century almost all elegant furni-
ure was japanned by these means; but it is now disused, except
or coaches, and for some small articles. The japanning of such
rticles as will bear the heat of a stove, to harden the varnish,
s now brought to a very high perfection, and is very cheap,
compared with the lac japan.

*Japanning of tin and paper wares by the stove*, is distinguished into two kinds; *clear work*, in which the japan is required to be transparent; and *black japan*, which is opake.

The varnish for *clear work* is composed of raw linseed oil, umber, and a little amber, with a small portion of white rosin boiled for several hours in a cast-iron pot, which is set in brick work, over a furnace, and the mouth of the pot surrounded by a funnel or chimney of brick work, with only one opening to obtain access to it; and this opening is provided with an iron door to shut close, in case the materials should take fire. The boiling is continued until by letting fall a drop on a cold tin plate, it keeps in a circumscribed spot. This varnish is mixed up for working with spirit of turpentine, the varnish being a little warm.

The *black japan varnish* is made by the same process, but asphaltum is used instead of amber; and it is thinned for use with tar spirit, instead of spirit of turpentine; lamp black also is added to the varnish.

Either of these varnishes are to be laid upon the work with a soft hog's hair brush. The work is left for a few minutes to set, and it is then put into the drying stove for thirty or forty minutes; it may then be taken out, and suffered to cool previous to varnishing again. The proper time for the second application is, when the finger will not slide over the surface at the same time that there is no actual sticking to the finger. After several coats have been applied, the work is left in the stove five or six hours, or all night, to harden or dry off the varnish.

If it is the clear varnish which is thus treated, this time will be sufficient; but it will grow darker in proportion as it is longer exposed to the heat, or as the heat is increased. For black work the heat is raised as high as possible, without melting the soldering, or charring the varnish; and this is continued three or four days. This process makes the hardest and most durable of all varnishes, and of a most brilliant jet black colour.

*Mottled Japan, in imitation of Tortoiseshell.* This is done by covering tin plate with one coat of varnish as above, mixed with Venetian red, and then it is coated with black varnish. The fingers are drawn over the varnished surface in a waving direction, to distribute the varnish unequally, and thus cause the red colour to be seen through in spots or clouds, imitating tortoiseshell. Otherwise the tin is painted in spots, with vermilion mixed in shell lac varnish; and this is coated with the clear varnish, which is afterwards stoved till it becomes deeply coloured, and is rather opake, so that it shows the ve

ion spots and the surface of the tin beneath in an imperfect nner, and much resembles the clouds of tortoiseshell. Some ple articles in wood may be treated in this way; for instance, lking canes are most beautifully ornamented at Birming-

hese processes of japanning by heat are to be found in some eipts by Kunckel, but do not appear to have been practised the Birmingham manufacture was begun.

When ornamental painting or gilding is required, it is done n a clear japan ground, when the same is set. A layer of d size being spread over the surface, the leaf gold or gold vder is applied, and also the required painting. Stencils sometimes used to lay the gold powder in particular patterns. variety of different coloured metallic bronze powders are d in the Birmingham ware; and for the smaller parts, they them on with stump brushes.

*Transparent Japan, or Pont-y-pool Japan.* The articles anned in this way are prepared by a good ground of black rnish, made very smooth; a layer of gold size is then laid , and the whole surface is covered with silver powder. Upon s is laid a coat of thin varnish, mixed with the desired co- r. When this is dry, it is sized over, and painted or orna- nted with gilding in silver leaf or powder. The whole is coat- with an external varnish of a gold colour, which changes the our of the silver leaf to that of gold.

Crystallized tin plate, or moiree, covered with a fine transpa- nt varnish, affords a beautiful article.

The stoves for japanning are built of brick or stone, gene- ly three stories high, with three stoves upon each floor. The e is at the bottom, and is covered over with a strong iron te. The flues are carried up at the sides and ends of the ves, and are made to afford three different degrees of heat; r drying off the clear varnish, or for darkening it, or for rkening the black varnish.

## *White Wax.*

This is obtained by bleaching bees' wax by exposure to the n and rain during the heat of summer.

Bees' wax collected in different districts varies much in the se with which it may be bleached, and some cakes retain eir yellow colour with such obstinacy as to be totally unfit r the purpose of making white wax.

The wax is therefore assayed by scraping off a little from e top and bottom of each cake, putting the shavings into a x divided into partitions which are numbered, and a corres- ndent number marked on the cake. The box is exposed to

the sun for some time, and a memorandum is kept of the [illegible] required for bleaching the shavings of each cake. When the bleaching process ceases, the cakes of wax are sorted into three qualities, namely 1st, 2nd, 3rd, white, and fourthly, yellow or gray white, and unbleachable wax. The cakes of the first qualities are mixed with those that have been adulterated by the farmer with tallow or rosin, and sold for rubbing furniture or for giving toughness to the tar used for tarring ropes.

The cakes of the three first qualities are melted [illegible] by itself, in a tinned copper caldron having a pipe and cock about one-third its height from the bottom. Water is then poured into the caldron, but not so much as to reach the discharge cock. The wax is then added, being first cut into pieces, and a gentle heat applied. When the wax is melted, four ounces of cream of tartar are added to each cwt. of wax, the whole well stirred together, and then allowed to settle, after which the discharge cock is opened and the wax run out into a wooden cistern placed so as to be kept warm by the fire. Here the wax is allowed to settle again, and then to flow, while scarcely liquid, through a cock, upon a cylinder of wood turning in a trough of cold water, by which it is formed into thin ribands.

These ribands are exposed on hurdles to the sun and air, and when no longer altered, the wax is remelted and formed again into ribands, and thus successively until the bleaching is completed. The ribands of bleached wax are then collected together in fine weather, remelted and strained through a sieve into moulds, either for cake or block white wax. If the wax was taken off the hurdles in rainy or moist weather, it would acquire a grayish tinge on being melted.

Many attempts have been made to bleach wax with oxymuriatic acid, but although the colour is changed, the wax becomes brittle, losing entirely its ductility, so that the manufacture with this agent has been obliged to be given up. The bad effects of the oxymuriatic acid are in other cases guarded against by the use of alkalies, but these cannot be employed in respect to wax, as they act themselves so much upon it.

### *Purified Rape Oil.*

To one hundred gallons of rape oil add two gallons of oil of vitriol, mix and agitate them together. Upon this the oil presently changes colour, becomes thick and assumes a black greenish appearance. After three quarters of an hour it is full of flakes; at which time cease to agitate, but add 50 gallons of water to carry off the sulphuric acid, which, if

ed to remain too long, would act too strongly upon the oil, d carbonize it. It is necessary to heat this mixture during a least half an hour, in order to bring the particles of oil, of id, and of water, into contact with each other; after which i must be left to settle. After about a week or ten days' rest, t e oil swims above the water, and the water above a blackish s bstance precipitated from the oil by the sulphuric acid, which s bstance is the colouring matter of the oil, and prevents it f m burning well. Even after this period of rest, the oil t t forms the upper station is far from being clear, and it would p rhaps require twenty days to render it transparent by rest a ne; but by filtering the oil, it immediately becomes perfect- l clear and pellucid. By this process an oil is obtained infi- r ely more free from colour, taste and smell, than that com- r nly employed, which burns with the greatest ease, and in a respects worthy to be compared with the purest oils of c mmerce; add to which, that the loss in quantity is very in- c nsiderable.

If it be desired to obtain a still whiter oil, it may be subject- e to a second process; but then one gallon of oil of vitriol will s fice for 100 gallons of oil. In purified oil this acid does not c se a blackish sediment, but, on the contrary, of a grayish w ite, and in no great quantity. This sediment separates less e sily from the oil than the preceding.

This oil gives a brilliant light, but inferior to that of the oil c sesamum, *huile de cameline*, which is mostly burned in the s eet lamps of Paris.

Mr. Field's apparatus, fig. 359, and 360, is well adapted for filtering this and c er oils, as it allows nearly the whole pressure of the atmosphere to force the c through the filters.

### *Ceromimene.*

Braconnot and Simonin have endeavoured to use the stearine, c solid part of animal fats, as a substitute for wax.

The suet, or fat of any animal is diluted with oil of turpen- t e, and pressed in boxes lined with felt, the sides and bottoms c which are pierced with small holes; the stearine that remains i the box is then boiled a long time in water, to get rid of the c our of the turpentine. It is then melted, and fresh heated l ne black is added; after some hours' fusion it is filtered while l iling hot.

In this state the ceromimene, or prepared stearine, is bril- l nt, white, and semi-transparent, but extremely brittle; to g ve it sufficient tenacity for moulding, a fifth part of bees' w x is melted along with it; or it may be hardened by a slight e posure to oxymuriatic, or muriatic acid.

The oil and elaine expressed from the fat are separated distilling off the oil, and the elaine being purified by b black may be used for making soap; but the smell is rather d agreeable.

*Sealing Wax,*

Is a kind of cement made by melting lac, or rosin, with t pentine and colouring materials.

The Indian sealing wax is made by melting stick lac witl very small quantity of Scio turpentine and Chinese vermilic

The best Dutch sealing wax is made by melting four poun of light coloured shell lac, adding first a pound of Venice t pentine, and then three pounds of Chinese vermilion, stirri all well together, and when it is nearly set, a quantity su cient for six sticks is taken and weighed.

The sticks are made on a marble slab fixed in a frame, w a chafing dish placed under the slab to keep it properly heate The sealing wax is first rolled upon this slab with the han until it is reduced to a roll nearly the length of six sticks, a then brought to the exact length by being rolled with a squ piece of hard wood with a handle.

The sticks are then transferred to another workman, v rolls the stick upon a cold marble slab, with a marble rol until it is quite cold, and then polishes it by holding the st between two charcoal fires, placed at a small distance oppos each other, until the surface is become smooth by beginning melt, keeping the stick constantly turning. As the long sti grows hard the length of each of the six future small sticks deeply indented in their proper places.

A third workman breaks the long stick into small sticks, a finishes them by holding the ends to the flame of a lamp, a impressing on one end the manufacturer's mark.

Oval, channelled, or ornamented sealing wax is made pouring the mass into steel moulds.

Golden sealing wax is made in a similar way, only substit ting powdered yellow mica, or cat gold, for vermilion. T lac and turpentine, forming a brownish red transparent ma which allows the scales of the mica to be seen, and forms kind of avanturine.

Sealing wax is made of other colours by substituting the d ferent metallic colours for vermilion; and it is sometimes ev marbled, by working together different coloured wax just re dy to set. The French even perfume it with essence of mus or any kind of essence.

Sealing wax of inferior quality is made by substituting ros in part or even entirely for the lac; red lead or bole for th

rmilion; and common turpentine for that of Venice. A false pearance is given to the surface by softening the sticks between the two fires, and rolling them in a box of powdered ling wax of a better quality; the sticks are then again softed between the fires to melt this false coat and give the wax e last polish.

Black sealing wax is made from dark coloured shell lac melted with common turpentine, and coloured with lamp black.

### *Soft Wax.*

This is made by melting 20 pounds of block white wax with e pounds of Venice turpentine; and then stirring in a sufficnt quantity of vermilion or verdigris, in fine powder, to ve it the desired colour. The wax is then poured out on a b of marble or hard wood, moistened, and formed into large lls.

Soft wax is used for official seals, as requiring only to be ftened between the hands; it is also used as a cement.

### *Diachylon, or Simple Plaster,*

s made by putting five pounds of finely ground litharge into a copper pan, ling a gallon of ordinary olive oil and about two pints of water, heating and rring them all together, until the litharge is dissolved in the oil. When the ole is nearly cold it is poured out, and formed into rolls upon a marble slab. This operation requires care to prevent the heat from turning the plaster own; if it is necessary to add more water to moderate the heat, the pan ould be removed from the fire and let to cool a little before fresh boiling wa- is added.

Diachylon is used by the surgeons as the basis of many plasters, made by relting it and adding various resinous substances.

### *Purified Fish Oil.*

The finks, or Greenland blubber, produced from whales, is ought home, cut into small pieces, and packed in casks, and hen it arrives in England it is in a putrid state.

It should be started into a large back or receiver, containing out twenty tons; from thence the fluid parts are suffered imediately to strain through a semicircular wire grating, in the de of the back, close to the bottom. The grating should be out four feet wide and two feet high, receding in a convex rm into the back, and the wires sufficiently close to prevent ie finks from passing through. The oil, as it drains through is grate is to be conducted, by means of a copper pipe, into nother back containing about the same quantity. When this cond back is full it should be left about two hours to settle, ter which it must be conducted, by means of a sluice, into a pper, containing about fourteen tuns, heated by a fire in the sual way. The oil must then be kept stirring in the copper

until it has acquired heat equal to 225 deg. Fahrenheit, whi will destroy the rancidity of the smell, and also strike down the gross or mucilaginous matter to the bottom. As soon the copper of oil has received the before mentioned degr of heat, the fire must be immediately drawn, and about half tun of cold water pumped upon the surface of the oil. This sists in cooling the bottom of the copper, and prevents the gr and mucilaginous parts from adhering to the sides.

In this state the oil should remain cooling in the copper f the space of one hour, and should then be conducted into oth backs or coolers, and when perfectly cold should be drawn into casks. It will then be fine, and fit for immediate use.

Another method of sweetening, purifying, and refining Gree land whale and seal oil, is to filter the raw oil through bag about forty-one inches long, with circular mouths, extended l a wooden hoop, about fifteen inches in diameter, fixed theret These bags are made of jean, lined with flannel; between whi jean and flannel powdered charcoal is placed throughout, to a r gular thickness of about half an inch, for the purpose of reta ing the glutinous particles of the oil, and straining it from i purities; and the bags are quilted, to prevent the charcoal fr becoming thicker in one part than another, and to keep linings more compact. The oil runs from the filtering bags i a cistern, containing water at the bottom about the depth of f or six inches, in each 20 gallons of which is dissolved about ounce of blue vitriol, for the purpose of drawing down the g tinous and offensive particles of the oil which have escap through the charcoal, and thereby rendering it clean, and fr from the unpleasant smell attendant upon the oil in the ra state.

The oil is suffered to run into the cistern until it stands to t depth of about two feet in the water, and there to remain f three or four days (according to the quality of the oil;) and then drawn off, when it will be found to be considerably pu fied and refined; the oil, after having undergone this operatic may be rendered still more pure, by passing a second or thi time through similar bags and cisterns. But the oil, after su second and third process, is drawn off into, and filtered throug additional bags made of jean, lined with flannel, enclosed other bags made of jean doubled.

A third method of purifying fish oil, is to take one gallon crude stinking oil, and mix with it a quarter of an ounce of lit slaked in the air, and half a pint of water. Stir them togeth and when they have stood together some hours, add a pint water and two ounces of pearl ashes, and place the mixture o a fire that will just keep it simmering, till the oil appears o

ht amber colour, and has lost all smell, except a hot greasy p-like scent. Then add half a pint of water in which one ce of salt has been dissolved, and having boiled it half an ur, pour the mixture into a proper vessel, and let it stand for ne days, till the oil and water separate.

If this operation be repeated several times, diminishing each he the quantity of ingredients one-half, the oil may be brought a very light colour, and rendered equally sweet with the com- n spermaceti oil. Oil, purified in this manner, is found to rn much better, and to answer better the purposes of the wool- manufacture. If oil be wanted thicker and more unctuous, may be rendered so by the addition of tallow or fat.

For some purposes it is sufficient to add a pint of lime water each gallon of stinking oil, stirring them well together for e first day, then to let the mixture settle, and draw off the rified oil.

### *Neat's-feet Oil.*

This rises to the surface of the water in which neat's-feet and pe are boiled.

It is only used in England for greasing harness, as it keeps e leather moist longer than any other oil. In France and cotland it is used in cookery, particularly for making fritters.

## SOAPS.

Soap is a combination of an alkali with oil or fat; the only kalies used in making the soaps used in the arts are soda and otasse. Soap made entirely of soda is rather too hard for com- rtable use, and hence some potasse is generally added: those ade with potasse alone are soft and pasty. Soaps also differ reatly according to the oil used.

The pans in which soap is usually made, are heated only at ottom, which is also generally covered with alkaline ley, so hat the fire does not act immediately upon the soap. The French soap pans are a large flat plate of iron or copper with he edges turned up like a frying pan; and the sides are built p of brick or stone work. The English soap pans are large ast iron pots, merely set upon the fire-room, the sides being eft naked.

### *White Castille Soap.*

In manufacturing hard soap from olive oil the usual proportions are 600 pounds of oil, 500 pounds of barilla, and 100 pounds of quick lime. The lime is first slaked, screened, and mixed with the barilla, water is poured upon the alkali, and in

three or four hours runs off: this first ley, called *capital l* should show 18 or 25 deg. Baumé, or the spec. grav. of 1· to 1·21. Fresh water is again poured on the alkalies, and a cond ley obtained, showing 10 to 15 deg. Baumé, or the sp grav. 1·075 to 1·116. A third ley is then made, showing 8 deg. Baumé, or the spec. grav. 1·029 to 1·06. The fou ley, which exhausts the barilla of every thing soluble in wa is used to form the first ley of the succeeding operation inst of plain water.

The oil is then poured into the boiler, along with a portio the third ley, and the mixture made to boil; the remainde the third ley is added by degrees, and when this is consu the second ley is gradually added; the boiling liquor being quently stirred during the whole time. The oil turns mil and after it has been boiled some time it acquires a greater c sistency.

When this takes place the capital ley is added by degre and then the oil grows still thicker, and begins to separate it from the watery liquid. A quantity of salt is now added, wh renders this separation still more complete, and the soap is s perfectly formed in a kind of granulated paste; which, on w drawing the fire and allowing the whole to cool, collects at swimming on the spent ley, which is to be drawn off, an used to lixiviate the next mixture of kelp and lime, and t form a ley that is employed towards the end of a new boili

The fire being re-lighted, the remainder of the capital le added by degrees; and a small quantity of the soap taken from time to time, dropped on a slate to cool, and examin When the soap has been sufficiently boiled, and the ley on wh it swims has a spec. grav. of 1·150 to 1·2, it will appear when rubbed between the fingers, and in the boiler have the pearance of a dark gray paste, which may be made into wh or marbled soap. To make white soap, the fire is withdra and the soap suffered to stand for some hours; after which liquor, collected below the soap, is drawn off. The boiler now heated again merely to melt the soap, and a small quan ty of weak ley added. The colouring matter, which is a co bination of fat matter, alumine, and oxide of iron, not being luble in the soap at this temperature, falls gradually to the b tom, leaving the soap perfectly white.

Whilst the soap is settling in the boiler, the moulds are ranged, and a small quantity of powdered lime is spread as ev as possible on the bottom of each, that the soap may not adh to it. The soap is then ladled out or drawn off into the moul

After two or three days in winter, or more in summer, t soap will be sufficiently solid to be taken out of the moulds, a

ided into cakes. It is then conveyed into the drying rooms, it is not fit for sale until it no longer yields to the pressure the fingers.

Not more than five pounds of soap ought to be made from ee pounds of oil; that is to say, a thousand pounds of soap m six hundred pounds of oil; but some dishonest manufac- ers make one pound of oil into three pounds of soap, and n more.

The soap manufacturers of Marseilles follow this process; but h of them pretends that he has a peculiar secret of his own, ich he conceals with a great air of mystery.

### *Marbled Castille Soap.*

Marbled Castille soap differs from the ordinary white soap y by the colouring substances which are left in it, or are add- to it, in order to tinge it with blue and red streaks or spots.

When the boiling of the soap is finished, and the ley on which swims is of the spec. grav. of 1·15 or 1·2, the soap is, as has n already mentioned, of a dark gray colour, and loaded with ouring matter. To disperse this colouring substance in veins, s necessary to dilute the soap with a little water, and to let it l gradually. If too much water were added, and it is cooled slowly, all the colouring matter will fall to the bottom, and ve the soap white; if sufficient water be not added, and it is led quickly, it becomes granular, like moor stone.

If the quantity of colouring matter derived from the barilla not sufficient to colour the aluminous soap, a little copperas ter must be added. Whether this addition is necessary or t, there is added to the dark gray rough soap, the necessary antity of weak ley to bring it to the desired point of mois- e, after which it is run into the moulds as usual.

To produce the red colour, colcothar, or Spanish brown, is uted and mixed with water. A workman placed over the iler stirs the soap, whilst another pours into it the red colour- g liquid; and in order that this may mix in a uniform manner, e workman who stirs it takes care to make no other motion th his instrument than drawing it from bottom to top. The ap ought to be of the consistence of a paste when the red co- ur is added to it, and immediately put into the moulds. The ulding is somewhat more difficult with the marbled soap than ith the white, the latter being more fluid at the time when it run into the moulds.

Three pounds of olive oil yield five pounds of white soap; t the same quantity of oil affords only about four pounds and quarter of marbled soap. This is the reason why the latter nd is more solid than the former; and for the same reason also

laundresses prefer the marbled soap, there being a greater q tity of effective soap in a given weight of the marbled kin

This soap is preferred for exportation into hot countrie account of its hardness. The same hardness might be imp ed to the white soap by drying it more, which would give i the essential properties of the marbled.

### *Foreign Soft Soap.*

The ley of potash is prepared in the same manner, and w the same attention as those of soda. They will have all caustieity that is required, if 80 lbs. of lime are taken to a of potash. This quantity of potash is in general sufficient converting into soap 160 lbs. of oil.

The manufaeturer ought to manage his boiler with all the cautions preseribed for the manufacture of hard soap. The wi of the ley whieh has been used ought to remain in eombina with the soap; it is, therefore, neeesssary that it should not suffered to separate from the paste, and that the latter shou prevented from elotting. The paste is reekoned to be suffici ly boiled when after eooling it is found to be perfectly uni and of a soft clammy consistence.

In manufaeturing this speeies of soap eare should be taken to make use of any soda or sea salt. These substances te give a hardness to the soap made with potash, and would in render it hard if employed in suffieient quantity.

Some soft soaps are green or black. When oil of hemps is employed, they are of a green colour without making farther addition. If rape oil is used, yellow soap is obtai the eolour of which is changed into green by adding a sm quantity of indigo during the boiling. When any colour oils, such as that of linseed is used, a green eolour may be gi to the soap by the addition of a yellow and blue pigment; nat ly, turmeric for the yellow, and indigo for the blue. These ferent oils are usually employed mixed together, and the ma faeturers have a habit of adding, during the boiling, a mixt of turmerie and indigo when they wish to have green soaps; when black soaps are wanted of them, they colour them by a ing, during the boiling, a quantity of sulphate of iron and coetion of gall nuts.

Hog's lard is also used instead of oil in manufacturing soap for the toilette.

### *White Curd Soap.*

This is made of tallow only, and is the best of the Engl soaps in common use.

The boiler must be perfectly elean, and if 10 cwt. of b

me melted tallow is to be made into soap, add to it 200 gal-
ns of ley. The fire must be moderate as the goods are apt to
il over. The boiling is continued about two hours, and the
e being withdrawn, the goods are left to settle for another two
urs, and then the ley pumped off. As the ley separates
ickly from curd soap, two or three boils a day may be given
th ease, until the soap appears something like a curdy mass,
d when pressed between the finger and thumb, forms a thin,
rd, clear scale not sticking to the finger. Then withdraw the
e, add a few pails of cold ley, and when settled pump the ley
an off.

To wash this soap, light the fire and add 90 or 100 gallons of
ter. When the goods are melted and have boiled some time,
y, on a board held sloping, if the ley runs from the soap, if so
d more water; if it do not run, or there be no appearance of it,
il for a short time, then add about 3 gallons of salt and 6 of
ter mixed together, which will soon separate the soap and
ter from one another. When this is done withdraw the fire,
d in about half an hour pump off the water, which will bring
th it most of the remaining ley of the former boil.

The fire is again applied, 60 or 80 gallons of water added,
d boiled for some time; examine if the water runs from the
p, if it does, add more water in small quantities, until in-
ad of running from the soap, it appears only just starting
m it. Then increase the fire so as to swell the soap up to
e brim of the pan; withdraw the fire immediately, cover the
n to let it cool gradually for twelve or fourteen hours, or even
nger. If the soap has the slightest blue cast repeat the wash-
g.

The moulds for white curd soap should be lined with coarse
oth used only for this purpose. After it is put into the moulds
d well stirred, the mould should be covered with coarse linen,
atting, and the like, that the soap may cool slowly and uni-
rmly. A cwt. of tallow is computed to make 3 cwt. of white
rd soap; but it is seldom that so much can be obtained. The
y is usually made of 3 cwt. of American potash with 5 cwt. of
rilla, but kelp is sometimes used, and as it contains much sul-
huretted hydrogen, and other impurities, the water pumped off
ill be of a dark bottle green colour.

Thirteen cwt. 2 qr. 16 lb. of tallow, 5 cwt. 3 qr. 12 lb. of ba-
lla, 3 cwt. 2 qr. 6 lb. of American potash, 4 cwt. 2 qr. 7 lb.
quick lime, and 3 qr. 16 lb. of salt, produced 24 cwt. 1 lb.
soap, with no more than 1 cwt. nigre or black ash.

White curd soap, scented by adding some oil of caraway seeds
st before it is poured into the moulds, is in great use as a toi-
tte soap, by the name of *Windsor soap*.

Tallow soap dissolved by heat in spirit of wine separates o the solution being cooled, and forms a *transparent cake of soa* at the bottom: this is used also as a toilette soap.

### *Yellow Soap.*

This is the common soap of England, and differs from cur soap by having rosin and palm oil added to the tallow.

A pan is usually charged with 150 or 200 gallons of ley, an then 10 cwt. of tallow, and 3 cwt. of rosin, broken into sma lumps, are added. The boilings are usually of two hours each after which the fire is withdrawn, and the pan left for five or si hours to settle, as the ley does not separate so soon from yello soap as from white soap; after which the ley may be craned o pumped off.

These boilings are continued until the soap is made, and form a thin hard scale when pressed between the finger and thumb Then give a quick boil, withdraw the fire, cool with 20 or 3 gallons of ley, and in two hours time draw off the ley; 60 o 80 gallons of water are then to be added to the pan, a brisk fir made, and the goods boiled until they appear like thin honey Trials are then made upon a board whether the ley runs cle from the soap, if it does, more water must be added, and th boiling continued. If no ley runs from the soap, too much w ter has already been added. About 1 gallon ½ of salt, and gallons of water are then poured in. When the ley is seen ju starting from the soap, 20 pounds of palm oil are added, and i about half an hour the fire withdrawn, the pan left for a couple c days to settle, and then poured into the moulds, where, in abou three days, it will become solid enough to cut into bars.

Thirteen cwt. 11 lb. of tallow, 3 cwt. 2 qr. 18 lb. of rosin, cwt. of palm oil, 6 cwt. 2 qr. 14 lb. of barilla, 1 cwt. 16 lb. c potash, 5 cwt. 9 lb. of quicklime, and 3 qr. 6 lb. of salt, yielde 26 cwt. 21 lb. of yellow soap, and 5 cwt. 3 qr. 4 lb. of nigre c black ash.

### *Mottled Soap.*

This is made from yellow soap by adding copperas water, an afterwards some colcothar or Spanish brown, as already men tioned.

### *Soft Soap.*

This differs entirely from the hard soaps, in that the alkalin basis is only potash: 100 gallons of this ley is put with 28 pounds of tallow, and when this is melted, 82 gallons of whal oil are to be added. The fire is then withdrawn for two hours and afterwards re-lighted, and 20 gallons more of ley added

nd boiled until the soap is half finished, when 10 gallons more ey are added, and afterwards, at different times, and by small uantities, 10 gallons more ley. The fire is now withdrawn, nd the soap ladled into barrels, firkins, or other casks.

Two hundred and seventy-five gallons of whale oil, and 4 wt. of tallow, boiled first with 252 gallons of potash ley, con- aining 15 ounces and rather more of pure potasse in the gallon, nd afterwards 294 gallons of potash ley, containing 1 pound ¼ f pure potasse to the gallon, added in separate parcels of 42 allons each, produced 6400 pounds of soap; so that one-half as merely water.

## SUGAR.

This is obtained from the juice of the sugar cane, which is con- eyed from the mill to a clarifying boiler, of which there are enerally three in a boiling house, used alternately. As soon s the clarifier is filled, the fire is lighted, and to every 100 allons of cane juice, ½ a pint of lime in powder is added. The quor is heated and scummed, until the scum begins to rise in listers, which break into white froth; but it must not boil: this enerally takes forty minutes. The fire is then damped, the quor left for an hour to settle, and then drawn off clear, into he largest of the three, or which is most usual, four evaporating oilers. Here the liquor is allowed to boil, and carefully cummed, until it is reduced so low as merely to fill the next ized boiler, where, if the liquor is not perfectly clear, a little ime water is added. When sufficiently reduced in quantity, it s ladled into the next boiler, and from thence, in due time, into he smallest, called the *teache*, where it is still farther evapo- ated, until it is reduced to a thick syrup, and the thread it orms, when taken from the ladle, between the finger and thumb, reaks when it is an inch long. From the teache the liquor is adled into the coolers, of which there are generally six in a oiling house, 7 feet long, 5 or 6 feet wide, and 1 foot deep: the lower it cools, the larger is the grain of this *brown* or *musco- ado sugar*.

All the above operations are carried on night and day with- ut ceasing during the crop time. The clarifiers and boilers nust be proportioned to the quantity of juice that the mill can grind, and the richness of the soil. Thirteen hundred gallons f cane juice from a rich soil, will make a hogshead or 16 cwt. f sugar, which would require more than double that quantity of uice from a poor soil. Some water mills grind with ease as many canes as will make 30 hogsheads of sugar by the week. Three clarifiers of 300 or 400 gallons each, are judged sufficient

for a plantation that makes from 15 to 20 hogsheads by th week: the boilers diminish gradually in size, and the teach usually holds from 70 to 100 gallons.

From the coolers the irregular mass of imperfect crystal mixed with molasses, is put into hogsheads without heads, place on a frame over a molasses cistern; eight or ten holes are bore in the bottoms of these hogsheads, and these holes are plugge up with the stalk of a plantain leaf. The molasses drains throug the spongy stalk, and in about three weeks the sugar become tolerably dry and fair.

The molasses is used as the material for distilling rum.

### *Clayed Sugar, or Lisbon Sugar.*

This is a half refined sugar, obtained by a more perfect drain age of the molasses than in muscovado sugar.

The drained sugar is taken from the coolers already men tioned, and put into conical earthen pots, placed in a frame wit the points downward over earthen jars to receive the molasses This point has a hole of about ½ an inch over, closed with a plu which, as soon as the sugar is cold and become solid, is remove and the molasses drains from it. To get out still more of th molasses, the upper surface is covered with a layer of cla moistened with water, which, oozing through the clay and s gar, carries with it the remaining molasses. By repeating th addition of moistened clay the sugar is rendered still finer a lighter coloured.

### *Refined, or White Loaf Sugar.*

A number of processes are used for refining the muscovad sugar into loaf sugar, and from the extent to which the manu facture is carried, any improvement in it is a sure source of grea profit to the inventor.

The usual method was to charge the boiler with lime wate to light the fire, and dissolve in the water the muscovado suga that was to be refined; a quantity of eggs, or blood was the added and stirred in, which coagulating rose with the impuritie of the sugar into the scum, which was taken off. The refine syrup was then poured into conical pots placed on their point in which is a hole, stopped at first, but afterwards opened to le the treacle drain off. The top of the sugar was covered wit wet clay, the moisture of which ran through the sugar, and ca ried off still more of the treacle. When the treacle ceased t drain off, the pots were set on their broad ends to diffuse th last remains of the treacle through the sugar, and then stove for several days to dry the sugar perfectly. Sometimes th

lution of the sugar and purification were repeated twice or rice.

The following improvements have been made in this process.

1. To moisten the raw sugar and press it before it is refined, uch of the treacle is carried off, and some pure sugar, the re- ainder is left dry, whiter than before, and is much sooner re- ned. The liquid part not being injured by heat may also be ade into an inferior kind of loaf sugar.

2. To heat the sugar pans with steam, either by enclosing the n in a jacket, or by having a coil of pipe at the bottom of the n; the jacket or pipe being filled either with steam at the or- nary pressure, or with high pressure steam in order that the rup may be made to boil.

3. To heat the sugar pans by a coil of pipe, through which a rrent of hot oil is made to pass, by a forcing pump worked y a steam engine; the oil being heated in a vessel placed on e side.

4. To clarify the solution of sugar by adding from two to five ounds of bone black to each cwt. of sugar that is dissolved, revious to the addition of the eggs, or blood.

5. To remove the pressure of the atmosphere from the sur- ce of the boiling liquid in the pan, in order that it may boil a less temperature, and, therefore, that less of the sugar may e converted into uncrystallizable syrup, or treacle. This pres- ure may be removed either by means of covering the pan, thus onverting it into a retort, and extracting the air by an air ump; or the pan being converted as before into a retort, the air ay be driven out in Barry's method by steam, which, after aving done this office, is then employed in heating the pan. The condensation of the steam raised from the pan is effected y Barry's patent by a condensor, upon the principles of Prof. olimani's dephlegmator, as delineated in fig. 224, *h*.

6. To filter the evaporated syrup through numerous folds of anvas, by either removing the air by pumps from under the fil- ers, and thus forcing the liquor through them by the pressure f the atmosphere. Or by closing the filtering chest at top, air s forced in by condensing pumps, and by its compressing power he liquor is forced through the filter.

7. Instead of lime only, sulphate of zinc is used to purify the sugar. The pan is charged with strong lime water, and the su- gar added. When the sugar is all dissolved, four ounces of sul- phate of zinc is taken for every cwt. of sugar, dissolved in as little water as possible, and stirred into the pan. If the raw su- gar contains much acid, take one-fourth as much lime as of sul- phate of zinc, mix it into a cream with a little water, and add it to the pan about five minutes after the sulphate of zinc, which

latter being decomposed by the lime, the oxide unites with t extractive matter, tannin, and gallic acid, and renders them i soluble.

8. In regard to the drainage, Mr. Drake puts a piece of dan calico upon the sugar in the mould, and on that two or thr inches deep of plaster of Paris, mixed with three times as mu water. This is renewed every other day for eight or ten day or longer if the loaves are large.

9. Another method of drainage was founded by Mr. Howa on the principle of water, although saturated with one salt, b ing capable of dissolving another. In finishing, therefore, t lumps he poured on the sugar in the moulds, a syrup made strong of sugar as possible, which dissolves the treacle as passes through the mould, but leaves the sugar untouched.

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Sugar is extracted also from other articles than cane juice, from the sap of the maple by the American cultivators, the s of the walnut tree by the Tartars, the juice of apples, or pea the acid being previously saturated by chalk, and from beet ro but these are only substitutes employed when the cane sugar from accidental circumstances, not to be had but at a price mu higher than usual.

Sugar is used as a sauce to many kinds of culinary preparations, as puddin fruit pies, and dressed fruits. It is also used to sweeten many kinds of drin Considerable quantities are made into ale and wine, by being flavoured w other materials; it is also much used in preserving fruits and the other edi parts of plants; and as an adjuvant in preserving animal substances.

### *Syrups.*

Formerly upwards of a hundred syrups were made and ke in large quantities in the apothecaries' shops; at present it only the clarified syrup sold by the name of capillaire, and c louring, that are manufactured in large quantities; for the co sumption of syrup of buckthorn by the farriers, and of syru of violets by mothers and nurses, is greatly diminished.

The *capillaire* of the shops is made by dissolving in wat the broad ends only of the sugar loaves without breaking bruising them, as otherwise the syrup would be cloudy, addi to each pint of the syrup an egg broken in pieces, (the shell b ing put in not to lose the white sticking to it,) and after stirri the whole well together, giving it a boil and straining throug a flannel, or rather a tamis. When cold, to each pint there to be added about an ounce of either orange flower water rose water, or both. Some, to give a rich appearance to the s

, dissolve gum tragacanth in it, but then it does not mix well th wine, the gum separating in threads. Capillaire is used to x with fair cold pump water to form an agreeable summer nk, which is also esteemed highly restorative. Common ca- laire, made with plain water only, is also made by publicans sweeten their mixed liquors, as brandy and water, and the e, quicker than by putting in lumps of sugar.

*Brandy colouring* is another syrup of which great quanti- s are manufactured. Brown sugar is put into an iron pot, ated till it melts, and stirred till it becomes of a dark colour, d begins to grow bitter; lime water is then added to form it o a syrup, which is used to communicate a reddish brown co- ur to brandy, and this gives it the appearance of having been pt long in an oak cask.

## FARINACEOUS SUBSTANCES.

### *Flour.*

The mills which grind wheat for the London markets use three dressing ma- ines. The upper part of the cylindrical sieve of the first machine is a wire th of 64 wires to the inch, the flour that passes through this is called fine ur; the other part of the cylinder has fewer wires and suffers a coarser flour, led middlings, to pass through it, while the bran and coarse pollard fall out the end of the cylinder. The middlings are ground over again in a pair of ll-stones which are rather dull, and become unfit for grinding corn without essing them again. Then, after this second grinding, the meal is dressed in e machine, called the bolter cloth, which allows the second flour to pass, and e pollard comes out at the end of the cloth. The bran and the pollard to- ther are now put into the cleaning off machine, which is a coarse wire cylin- r, and by it is separated into hog pollard, which is the finest sort, horse pol- rd, and bran. A pair of mill-stones, when in good condition, will grind five ushels of wheat in an hour; but require to be taken up and dressed once a eek, if used constantly.

Accum says that 8 bushels, or 32 pecks of wheat, will yield bushels 3 pecks of fine flour, 2 pecks of seconds, 1 peck of ne middlings, ½ peck of coarse middlings, 3 bushels of 20 enny flour, 2 bushels of pollard, and 3 bushels of bran, being, n all, 14 bushels 2 pecks ½, so that its bulk is almost doubled.

For household bread the corn is passed only once through the stones. A ushel of wheat of 61 lbs. produced 60 lbs. three-fourths of meal and bran, which, by dressing, were separated into 48 lbs. of household flour, being four- fifths of the wheat, 4 lbs. one-fourth of fine pollard, 4 lbs. of coarse pollard, nd 2 lbs. three-fourths of bran, 2 lbs. being lost in dust.

For ammunition bread, the miller is required to furnish for every five quar- ers, or 2280 lbs. of wheat, 7 pecks, or 1960 lbs. of flour; this is 52 lbs. 7 oz. for 61 lbs. of wheat, or nearly five-sixths.

The millers about London and other sea ports, reduce their flour to the price of the market by mixing with English wheat or flour, foreign or American, as also Indian meal and rye; for buck wheat is too scarce and millet too dear: they can also sell their pollard for gingerbread and brown biscuits. The inland mil-

lers cannot obtain the same price for their flour, and are obliged to m by grinding about one-third of beans with the wheat. Having scarcely sale for their pollard, they are necessitated to buy hogs to eat it up, and fa for the knife. Both sea-port and inland millers feed their horses upon bran they have no vent for it.

Liquid ammonia, the liquor ammoniæ puræ of the chemists and druggi poured upon wheat flour turns it yellowish, but if any other flour is mixed w it the colour is more or less brown; and if peas and beans are used by the m ler, the colour produced is dark brown.

Millers are accused of adding bones, plaster stone, whiting, and Derby white with their flour; but this accusation is false, as these additions would instantly detected by the baker, from the flour after being squeezed in t hand breaking down immediately. Flour has, indeed, been manufactured w these substances for the purpose of cheating government, by depositing it their warehouses in the place of so much foreign corn taken out without pa ing the duty, and becoming intentionally forfeited has been seized, sold, a thus found its way into the market.

Sand is also mentioned as an intentional adulteration of the flour by the m ler, but all flour ground between stones necessarily contains some of this su stance from the wear of the stones. Lately this detriment has been more abu dant than usual, as during the war the millers could not obtain the hard bul stones from the banks of the Rhine, and were obliged to use soft Welsh ston or even common sand stones, which wore down very fast. The mill-stones Switzerland are extremely soft, and the sand mixing with the flour is thou to occasion the bowel complaints so common there.

Many families in the country grind their corn in small mills at home. S mills cut the corn rather than grind it, and hence they introduce much of bran into the flour. Williams' mill (Trans. Soc. Arts, for 1814) in which side of a cylinder of French buhr-stone works against a breast-stone on a mo able carriage, is an excellent family mill, though it grinds slowly. Rustall's mily mill (Trans. Soc. Arts, for 1800) in which a small circular stone is tur vertically against another, grinds double the quantity. His box for the sift the flour should have two or three sieves of different fineness, for it is a b practice to pass the corn only once through the mill; it should be ground twi the stones not being set close the first time, by which means the corn bei only crushed, a large clear flake bran is obtained. The fine flour obtained this grinding being sifted from the middlings and bran, may be reserved pastry, without much injuring the colour of the remainder, especially if t middling flour being sifted from the bran in a coarser sieve is ground over aga the stones being set closer to improve its quality. The greatest inconvenien of these family stone mills is, that when they wear smooth there is some dif culty in getting them repicked. When a family grinds their corn at home th can mix their wheat with buck wheat, and thus greatly improve the flavour their bread.

## *Bread.*

Three kinds of bread may be distinguished. In the firs called *unleavened bread*, flour and water is kneaded, either b themselves or with eggs, butter, sugar, and some other article and exposed to heat or to the open air, by which the dough reduced to a very solid mass, which is sometimes flakey, b never cellular or spongy.

In the second kind of bread, called *leavened bread*, the flou and water being mixed together, is either left for some hou in a thin and almost liquid state, that the sugar existing in th flour may be spontaneously changed into alcohol and carbon

id gas, and by their expansion by heat, render the bread, hen baked, spongy and light: or it has certain substances, called *rments*, added to it, which accelerate the fermentation of the ough. and cause it to take place simultaneously throughout e whole mass of dough.

In the third kind of bread, a cellular appearance is given to e bread by adding certain substances to the mixture of flour d water, which give a cellular appearance to the bread when ked, by the mere expansion of the gas disengaged from em by the heat, without producing any change in the con-ituent parts of the flour. As this kind of bread is seldom ade, unless a baker has a sudden call for a greater quantity of ead than he can supply in the ordinary way of business, it as had no peculiar name given to it.

Different flours and mixtures of flours vary in the quantity f bread that can be made from any given weight of them, and is commonly thought that the flour or mixture that produces e greatest weight of bread is the most profitable. Certainly is so to the public baker, who, if he can sell this bread at e same price with that producing a less weight, receives from s customers the value of the increased weight for mere wa-r. But housekeepers who make their own bread, ought to refer that flour or mixture which drinks up the least water in cing made into bread; as these loaves, although less in weight, ill go farther in satisfying the appetite: besides which, the iddle part of bread that contains superfluous water, crumbles way under the knife, and much is wasted in this manner. he preference given to white bread in towns, even by the oor, is thought to be owing to luxury; but, in reality, as white our drinks up less water than the brown, the white bread is ore economical than the brown; and the preference given to arises from observing that the weekly expenditure for bread s less for the best white bread than when cheap bread or brown read is used for a constancy.

Much of the goodness of bread depends also upon the knead-ng, which is of two very distinct kinds. In the kneading sed by the English and French bakers, much air is introduced nto the dough. The closed fists are slid under the mass in he trough, and the hands being then opened, a quantity of the ough is brought from the bottom of the mass and dashed down o the other end of the trough, this manœuvre is repeated un-il the whole of the dough has been turned over. The small-st number of these turns used by public bakers is four, six is he general number, and for choice bread eight: some have ven given twelve. By this introduction of air into the dough, t would appear that an acid, either the acetic or lactic, or even

both, is generated in the mass, the sour smell being ... ceivable in a bake-house; as well as a portion of sug... the proportion of sugar extractable from the bread is ... than from the flour, notwithstanding the necessary expe... of the greater part of the sugar of the flour in the ferme... and rising of the dough.

In the other method of kneading, or rather pressing ... dough, sugar alone seems to be generated, as may be jud... from the sweetness of the products. This method of pr... is used in treading the dough for sea biscuits, and little or ... air is introduced, particularly in the French method, where t... dough is covered with two cloths; the sweetness of these b... cuits is well known. At Bologna, Venice, nearly all Lomb... dy, and Rome, with its neighbourhood, the dough is knead... with a gramola, or indented pestle, like the dolly of our l... dresses; the bread thus made is described as less spongy th... the common bread, but so much sweeter that it may be, and ... eaten as a cake, by itself. Vermicelli and the other Itali... pastes are merely pressed by the brie, and although not ... posed to any fire, but dried in the air, they are very sw... tasted, particularly vermicelli. The imperfect kneading gi... to home-made bread by the cooks rather pounding the dou... with their fists than kneading it, is the cause of its sweetness ... some palates.

What effect is produced by the mill of Geneva, to which ... the bakers in that town are obliged, to their great loss of tim... labour, and convenience, to send their dough to be kneaded, h... not been published.

## *Leaven.*

The mixture of flour and water will enter into fermentatio... but this action proceeds very slow: 4 ounces of wheat flou... with a pint of water, kept in a warmth of 70 deg. Fahr. to... four days before it began to ferment. Another mixture ma... in the heat of summer, began to ferment in thirty-six hou... and in some days it became sour, and on being used to cau... the fermentation of fresh dough, the dough speedily becam... sour. The addition of an ounce of salt, or the impregnati... of the dough with carbonic acid gas, neither impeded nor p... moted the fermentation. By taking only 8 oz. of flour and ... pints of blood-warm water, and as soon as the sponge begins ... rise, on the second day, adding 1 lb. of flour and 4 pints of w... ter; and thus proceeding for a day or two, an original ferme... will be obtained, which being added to the mixture of flo... and water, for making bread, will determine the fermentati... to take place in three or four hours. It is probable that th...

rmentation would take place quicker if a little brown sugar as added, or if millet flour was used, as this is so much weeter than wheat flour; rye flour is also more easily ferment- d than wheat, but has a tendency to turn sour.

It is only under peculiar circumstances that a recourse to an original ferment nec ssary, for this ferment having been once obtained, and the dough near- ready for baking made from it, the fermentation of the next parcel of bread eadily put in action by reserving some of the fermented dough, and using for that purpose. It is more than probable that the original ferment of the ead made throughout France, Spain, and Portugal, was produced many cen- ries ago in Carthage, from whence the use of bread was introduced into Eu- pe, on the destruction of that city.

To preserve this reserved dough, or leaven as it is called, from growing sour, veral methods are adopted. In the north of England, the leaven for the next eek's baking is kept fit for use by being buried a few inches deep in a sack f flour. In Italy it is kept fresh even for three months by being buried very eep in flour. The French, if they intend to use the leaven in a few days, eep it in a warm place between two bowls, and add every day as much flour s the leaven weighs, and a sufficient quantity of water to restore the original onsistence; but if it is not to be used for a week or longer, the scrapings of he kneading dough is cut into small pieces, dried by a gentle heat, and when anted, rubbed down with warm water.

Except in a few farm-houses the fermentation of the dough is promoted, roughout the whole of the north of Europe, by the scum that arises in the rmentation of malt liquors. This yeast or barm is generally used in the pro- ortion of a pint to 100 lbs. of flour, and produces the fermenting action in the ough quicker than leaven. In general the yeast is dissolved in the first par- el of water with which the flour is mixed, and no leaven is used: but at Paris, nd other great towns in France, the dough is made with leaven, and a little east is added to the last parcel of water, merely to increase the sponginess of he bread.

If yeast is not to be purchased, original yeast may be obtained by boiling a uarter of a peck, 3 lbs. and a half of meal, for eight or ten minutes, in three ints of water, and pouring off two pints, which is to be kept in a warm place, he fermentation will commence in about thirty hours. At which time four ints more of a similar decoction of malt are to be added, and when this fer- ents, another four pints are to be added; and so on, until a sufficient quanti- y of yeast is obtained.

The French, under the name of levure, comprise not only yeast but the bot- oms of the beer, in the working tun and store casks. This is purchased by he yeast merchants, the beer drained from it through sacks, and the remainder of the beer washed out by putting the sacks in a stream of water; and the so- id matter left in the sacks is dried in the open air. The true yeast, or flowers of the beer, is also drained and dried for use in the same manner, as most of the Paris bakers prefer it in a solid state.

Dry levure ought to be yellow, brownish, or grayish white, by no means black or bitter. It should not yield to the pressure of the fingers, and be equal- y dry throughout, so as to break with a smooth surface. When dissolved in hot water, and a few drops of the solution are poured into boiling water, they should immediately rise to the surface.

In Edinburgh the bakers multiply their yeast daily by mixing 10 lbs. of flour with 2 gallons of boiling water, and covering it up for about eight hours. Two pints of yeast, made the day before, are then stirred in, and in about six or eight hours as much new yeast will be generated as is sufficient for 1 sack and a half, or 420 lbs. of flour.

When original yeast is prepared from malt, the fermenting wort may be add- ed to the flour as well as the yeast, according to Mr. Stock, whose patent sub- stitute for yeast is merely wort in a state of fermentation. The wort being

made from 2 lbs. of malt, one-fifth of an ounce of sugar, and 1 ounce of hops to each gallon. Two gallons of this wort are sufficient for 12 bush. of flour.

The Hungarians prepare a similar ferment for keeping all the year, by boiling in water in the summer, wheat bran, obtained in grinding for household flour, along with hops; the decoction soon ferments, and then a sufficient quantity of bran is flung in to drink up all the liquid, and allow it to be formed into balls, which are dried in a gentle heat. When wanted for use, some of these balls are broken, and boiling water poured upon them, which after some time is strained off, and used to make up the dough.

In like manner the Romans prepared their ferment, by drawing off in the vintage time, a quantity of grape juice while at the height of its fermentation, pouring into it a sufficient quantity of millet flour to drink it all up, and forming it into small balls, which when wanted were broken, infused in boiling water, and the whole was mixed with the dough.

A similar ferment may be prepared in this country from raisins; the raisins must either be pressed between boards with a heavy weight, or mixed up with the ground millet, as otherwise the strongest part of the must would remain amongst them.

In summer the leaven, yeast, and even dough, is apt to turn sour, and give a sour taste to the bread; this is remedied by stirring a few tea spoonsful of carbonate of magnesia into the ferment or dough. The Swedes, however, prepare a sour yeast to ferment their sour sweet bread for summer use. Into a small barrel, open at one end, which the oftener it has been used for this purpose the better, they put some rye flour, and pour on it boiling water to form a sponge; to this they keep adding by degrees more rye flour and boiling water. It quickly ferments, and as it swells is allowed to run into a bowl by a hole which is driven into a hole in one of the staves near the top.

It has been affirmed that flour kneaded with water saturated with carbonic acid may be made into bread without any yeast; others deny it: the difference in these assertions, probably, depend on the method used in forming the sponge. As flour and water will ferment of themselves, but the dough turn sour before it is fit for use, it is probable that the use of water saturated with carbonic acid gas may, if the sponge be made very thin, determine this fermentation quicker, and enable the sponge to be brought forward by degrees, to a fit state for making dough of the requisite stiffness.

When the baker has not sufficient dough ready for the oven the deficiency is made up by dissolving for every four pounds of flour 1 ounce ½ of volatile salt, the common subcarbonate of ammonia, in the water, intended to make the dough. This being properly kneaded may either be baked immediately, or in a short time. This bread is porous rather than spongy and bladdery, the cells being numerous and excessively minute. It has a slight tinge of yellow, and a slight unpleasant flavour, scarcely perceptible if the baking has been properly performed.

The oven, or furnace in which the bread is baked is generally built of brick in this country, but on the continent they prefer stone, as being easier and more regularly heated, and retaining the heat longer. Our ovens are circular, from three to twelve feet in diameter, and the crown of the arch is from two

three feet high, the door being twenty-four inches wide, and
velve high, arched at top. Most persons are fond of large
vens, on the supposition that they require less fuel to heat them;
ut two or more small ovens will, however, be found far pre-
rable, even by public bakers. In London, where baking of
eat and pies forms a large part of the baker's business, and
he oven must be kept hot during the whole of the day, the
eat is retained by making a fire place on one side a little below
he level of the floor of the oven, from whence a flue passes in
everal turns under the oven floor, and then round the side, from
hence it passes into the chimney.

Mr. Losh's experiments, as already related, show the advan-
ge of having a fire grate near the back of the oven, to give air
o the fire behind. In the large French army ovens, and those
f Germany, three or four holes, three inches by four, are made
n the walls of the oven towards the back, even with the floor,
or the same purpose, and when the fire is at its height they are
losed with stone plugs and wet rags.

The great inconvenience of the common brick oven is, that
does not act well unless it is kept in such constant use as not
o be suffered to grow quite cold, or even considerably cool.
When heated from a cold state, the first batch of bread is never
o well baked as the succeeding batches; and hence some public
akers only bake a small quantity of inferior bread for their first
atch. There is also a great waste of fuel in suffering the oven
o get cold, for it takes three times the fuel to heat a cold oven,
s it does to keep up the heat for the succeeding batches, sup-
osing they follow each other quickly.

The perfection of fermented bread consists; first, in its exhi-
iting when the loaf is cut through, a pile of bubbles, or air
ells, gradually increasing in size as they approach the top,
where they should be very large: secondly, in the middle of the
oaf being equally dry as the part of the crumb next the crust,
nd not crumbling when cut. The first depends on the bread
eing thoroughly penetrated by the heat before the crust is too
ard to rise, and, therefore, this pile of bubbles can seldom be
btained except when brick or stone ovens, which have been
ome days in heat, are used, and the door kept closed. The se-
ond shows that the bread does not retain, either from deficient
aking, or the nature of the flour, or mixture of which the
read is made, a superabundance of water, which increases the
eight of the bread without adding to its nutritive power, 15 lbs.
f good wheaten flour ought not to drink up more than 10 lbs.
f water, to form a dough, which, when properly baked, will
roduce at most 20 lbs. of bread.

## *London Bread.*

The most usual mode of making of yeast bread by the Lo don bakers is to dissolve from 4 lbs. to 6 lbs. of salt in 36 lbs. hot water, and when the solution is cooled to about 8° d Fahr. 3 pints of yeast are added. In the mean time a sa 280 lbs. of flour, is sifted into a box with a lid so as to lie ligh and a hole being made in the flour the above seasoning is add mixed up to the consistence of batter, covered with flour, a the box being shut is covered with flannels. The quarter spon thus set is left for three hours, another 360 lbs. of warm wa is then added, and more of the flour kneaded into the mass, half sponge. When this sponge has been set about five hour the remaining portion of warm water, generally 108 lbs. added, the whole mass of flour well kneaded with it for mo than an hour, then cut to pieces and confined to one end of t box, and covered with a sprinkling of flour. In four hours is kneaded again for half an hour, and cut into loaves, whi are immediately put into the oven which is judged to be pr perly heated, when some flour thrown on the floor of it comes black very soon without taking fire: loaves are plac so close together as when they expand by the heat they squee one another into a cubical, or oblong form. They remain the oven about two hours and a half, and the bread when tak out is covered up to prevent, as much as possible, any furth loss of weight, which in the baking is about one-ninth of th weight of the dough, although it has increased in size to thr times its dimensions.

The sack, 280 lbs. of good flour, is calculated to make o an average, 80 quartern loaves; or 347 lbs. ½ of bread; but a flour varies in its power of absorbing water, so a sack of ord nary flour will sometimes make 86 loaves by absorbing 34 lb. 2 oz. of water more than in the former case.

In London, about half a pound of alum is put into the sea soning in the place of as much salt; this is supposed to mak the bread whiter, and to hinder the loaves from adhering to fast. Some bakers in poor neighbourhoods are said to mak their seasoning half alum and half salt.

If the leaven should turn sour, as will sometimes happe in summer, it will be necessary to sift some magnesia into th flour with which it is to be mixed.

The mistresses of families in London exert themselves to confine the con sumption of this bread to 6 lbs. at the utmost by the week for each person i the family, or about 13 ounces ½ for each daily; and if rolls or other bread bought, or much flour consumed in making puddings, the consumption of th

ad is expected to be proportionally less. As it is at present a great point English economy to discourage the consumption of bread and encourage t of meat, this bread is seldom eaten till it has been made 24 or 36 hours, l become hard and dry, so that it will require considerable mastication, and s a less quantity will satisfy the appetite, than when new.

The yearly consumption of butcher's meat in England is imated at 250 lbs. or about 12 oz. a day for each individual; ile in France the yearly consumption of each individual is imated at only 8 lbs., or little more than ¼ oz. by the day. e real fact is, that only about one-third of the population r taste butcher's meat; the lower classes and a great part of middling, using mushrooms of many various kinds to com- nicate the meat flavour to the roots and pulse which form e substantial part of their food, while in England these are ly esteemed as auxiliaries to the meat.

A few London bakers endeavour to make their bread fine and white; but the ater part take little pains to make good bread, because the great use of s, baked meats, and baked puddings in English housekeeping, and the ge- al want of ovens in the London kitchens, occasions bread to be bought of nearest baker, although it is confessedly worse than that made by another small distance farther, for the sake of not having so far to carry or fetch pans.

### *Home-made Bread.*

Household bread is made of household flour. It is now sel- m made by the public baker, but usually by those families the country who bake their own bread. As the brown flour tains more water after baking than the white, this bread of urse does the same, and hence it keeps moist longer than ite bread, but the middle crumbles away. The deficient eeding it usually receives, gives it an anomalous taste which me call sweet, others sour. Being unsatisfactory to the ap- tite, the good lady of the house flatters her self-love in ob- rving the increased appetite of her London guests, and as- ibes it to the excellence of her home-baked bread, that which ises from its imperfection.

Home-made bread is most commonly baked in brick or stone vens; but as these are seldom kept constantly in heat in pri- te houses, the bread is always imperfectly baked, and loaded ith superfluous water. The only way to avoid this would be, employ the oven daily in as many of the operations of okery as possible. Stewing, boiling, frying, and even broil- g on a gridiron, placed over an iron dripping pan, may be rformed in an oven nearly, if not quite, as well as on a nge. But as this would make a great alteration in kitchen anagement, it is preferable for small families to bake their ead in an iron oven. An oven of this kind, 20 inches from

front to back, 16 inches wide, and as many high, will ba
rather more than 20 pounds of bread at a time, each b ki
taking up two hours. In baking two batches of bread su
sively in a sheet iron oven of this size, which had been in u
for fifteen years, the time from the first lighting of the fire bei
five hours, there were consumed 6 pounds of Walls' end co
3 pounds of cinders, besides the wood used to light th fir
This oven was placed 14 inches above the grate of a fire-r
10 inches from front to back, 7 inches high, and 7½ in
wide, widening each way at top to 1½ inch on each side b
yond the oven. If an oven of this kind, instead of b
closed at top by a brick arch thrown over it, be covered wit
flat cast-iron plate, stewpans, saucepans, and frying-pans, m
be placed thereon, or flat cakes baked on it: and if a doub
sheet iron dish cover be placed upon this plate, a second over
useful for baking small pastry, puddings, or potatos, will b
formed.

For baking at home, upon a smaller scale, Holmes' over
which is a plain cast-iron closet, generally 15 inches deep, a
13 wide and high, with a couple of sliding shelves, and havi
on the outside of one of its sides a cylindrical lump, abou
inches long, and 2 wide, projecting from it. This oven be
fixed on one side of the kitchen range, so that the lump of ir
may project into the fire, a sufficient degree of heat is co m
nicated to the oven to bake small loaves, pastry, potatos a
pans of meat, or heat dishes and plates, without giving th
cook the least trouble. If hot closets of this kind were neatl
adapted to the stoves in dining parlours, plates or dishes mig
be kept warm in them, instead of plate warmers, which hinde
the radiation of heat into the room.

Those false economists who estimate the value of bread by its own ght
instead of that of dry flour it contains, have endeavoured to increase the w ht
of the bread by boiling, for example, 5 lbs. of bran in 4 gallons of wa r, s
as to strain 3 gallons ¾; .56 lbs. of flour made into bread with this water is
to have produced 83 lbs. of bread, while the same weight of flour with pl
water produced only 69 lbs. ½; hence the bran water loaves must have r ta
ed at least 12 or 13 lbs. of mere water in them more than the others.

Others have sought economy by mixing pulped potatos with flour, and i
is stated that 16 lbs. of raw potatos boiled, peeled, pulped, and knead d wi h
26 lbs. of flour, produced 40 lbs. of bread; now as 3 lbs. 3 oz. of fa in ca
be obtained at the utmost from 16 lbs. of raw potatos, this bread must h ve
retained about 8 lbs. more water than is contained in fine wheaten bre d.

## *Sea Biscuits.*

In making the best sea biscuits, or American crackers, th
fine stiff dough, on being beaten or rolled out on a dresser
with a mallet or roller, is doubled again, rolled or beaten, an

doubling repeated several times, by which means the bis-
ts split into flakes when broken.

The common biscuits used on board English ships by the
me of bread, differ only from American crackers by being
de of pollard. The dough is made up very stiff, without
her yeast or salt, and as it extends on being trod upon the
r, or beaten on a table with a brie, the edges are cut off with
pade. re-placed upon the mass, and again trod or beaten down,
render the bread flaky when baked. The baking is per-
med in very low arched ovens, or rather muffles, 20 feet in
gth, or even more, open at both ends, and the arch heated
flues from a fire at each end, but upon opposite sides. The
cuits being previously pricked, are put in at one end, on iron
tes, connected together by hooks and rings, or to an end-
s chain. The plates, as fast as they are filled, are drawn
rough the oven, and by the time they arrive at the other end,
biscuits are fit for use. These biscuits are very inferior
the leavened biscuits supplied to the French ships.

### *Gingerbread.*

Gingerbread is made by dissolving ½ ounce of potash and a
tle alum in warm water, which serves to melt 1 ounce of
tter, and mixing up with them 1 lb. of fine pollard, ¾ lb. of
eacle, and an ounce of mixed spices, into a stiff dough, that
quires to be put by for several days before it rises sufficiently
be put into the oven, and if kept even for many weeks is ma-
festly improved. The mixed spice is principally composed
ginger, to which is added cinnamon, nutmeg, and allspice;
the inferior kinds common pepper, and in the best and
armest sorts Cayenne pepper. Caraway seeds, anise seeds,
rrants, and sweatmeats are also added occasionally.

The alum is not necessary, for the gingerbread is equally
od if it be omitted; it is put in to hasten the ripening of the
ead for the oven, for this cannot be done by means of yeast
in ordinary bread. The butter might also be omitted, but
improves the flavour. The potash, when this bread is eaten
any quantity, cannot but have some injurious effect upon the
alth, and yet the presence of an alkaline carbonate seems
ecessary to combine with an acid in the treacle, and thus by
tting free the carbonic acid, causing the gingerbread to rise:
s place may, according to Dr. Colquhoun's experiments, be
lvantageously supplied by the subcarbonate of magnesia, usu-
ly called magnesia, in the same quantity, and the alum omitted
ntirely.

The substitution of magnesia for potash is attended with a

farther advantage, that by increasing its proportion the bre will be ready for the oven almost immediately. Flour and tr cle, of each 1 lb., butter an ounce, and an ounce or 1 ounce of magnesia, with the usual spices, made a good bread fit f baking in a few hours' time.

By disengaging the carbonic acid from the magnesia by t tartaric acid, gingerbread may be got ready for the oven in le than an hour. Two pounds of flour, mixed with ½ oz. of ma nesia, and the usual spices, and made up with 1 lb. ½ of treacl 2 ounces of butter, and the requisite quantity of water, in whi ¼ ounce of tartaric acid is dissolved, is fit for the oven in h an hour. Instead of tartaric acid, cream of tartar may be use for 4 lbs. ¼ of flour, mixed with 1 oz. ¼ of magnesia, and th usual spices, and made up with 2 lbs. ¾ of treacle, 4 oz. ½ butter, and the requisite quantity of water, in which 6 oz. cream of tartar have been dissolved, was ready for the oven i less than an hour, and the bread was well risen, but had a sligh ly sour taste, which some might esteem as an improvement.

The sesqui carbonate of ammonia, volatile salt, being used i stead of potash in the common process, and the alum omitte the bread is no sooner kneaded than it is fit for being bake and the gingerbread is extremely well flavoured, only the up surface is unusually dark and glossy. The same effects t place if a small proportion of volatile salt is added at any ti to the ordinary gingerbread dough by the baker, if it is not re dy when he wants it.

## *French Bread.*

The public bakers in France usually begin their bakings c several batches, (5 in the morning,) by adding 5 pints of wate to 3 lbs. of leaven, which they reserved from the last baking and a sufficient quantity of flour to make their first sponge which usually weighs 17 lbs. ½.

Five or six hours after, (10 in the morning,) 10 or 11 pint more water is added, and flour to compose the second sponge of 40 lbs.

Five hours after, (2 or 3 in the afternoon,) a pail, or 24 pint of water, with flour, are added to form the last or finished spong which will weigh about 120 lbs. About 3 lbs. of this spong are taken out and put between two wooden bowls, to form th leaven for the next morning.

One hour and a half afterwards, (4 in the afternoon,) 3 pail ½ or 4 pails, about 70 or 80 pints of water, and about 100 lbs of flour are added, which will make about 300 lbs. of dough.

As the first batch is seldom so well baked as the following tches, many bakers use only ½ a sack of flour, (160 lbs.,) in is batch, with leaven and water in proportion.

The dough being well kneaded, 80 lbs. of the dough are taken t for forming the sponge of the next batch, which is placed de until the dough now made is put into the oven.

The French dough is made so very thin, that the loaves will t keep their shape until they are put into the oven; hence ey are obliged to be kept in a cloth in a basket that will just ld them separately. They are also baked separate, that they y be crusty all round.

The flour for the second batch being put into the trough, a le is made in it, and this reserved 80 lbs. of dough is put into and left for about two hours, water is then added, with which e reserved dough is diluted so that no lumps can be perceived, d is then worked with the new flour for the second batch; lbs. being reserved as before for the third batch.

In this manner ten or more batches are made by most bakers: hers continue on for forty or even fifty batches in two days and ghts, without making fresh sponge as at first, but refresh the ugh every other batch after the fourth with a petit levain or bye onge. They take out of the third dough, besides the 80 lbs. r the fourth batch, about 12 or 15 lbs. which they immediate- mix with as much water, and the necessary quantity of flour, form the bye sponge for the fifth batch; and in like manner ey take out of the fifth batch of dough a bye sponge for the venth batch, and so on. These bye sponges are rubbed down ith water, and added after the reserved dough has been worked with the new flour.

Salt is seldom used in making bread in France, except for ose kinds that are made for soaking in soup or broth, being ought to promote their dissolution, and then 1 oz. for each lbs. of flour is the usual proportion.

If the bread is to have any salt or yeast put into it, this last ough is made up stiffer than is required for the bread to be ade from it; and when it has risen sufficiently, the salt and east are dissolved in a sufficient quantity of warm water to ring the dough to the requisite consistence, and this water is neaded into the dough, which is then set by to rise properly, nd when ripe for the oven is made into loaves, and immediate- y put into the oven, being at this moment brushed over with ater, to which some bakers add a little honey, yolk of egg, r milk. Yeast or levure is only used by the French bakers r the sake of making the dough in less time, as it renders the read less white, and the bread not to be so good tasted as the

bread made with natural leaven; but the working bakers pre yeast as diminishing their manual labour.

A quarter of a pound of yeast is esteemed equal in effect 8 lbs. of leaven: it requires 4 oz. of yeast for 20 lbs. of dou if no leaven is added.

After the yeast has been added, the dough is no longer fit leaven, as it will not keep.

The usual consumption of a French family is estimated 9 lbs. of soft bread by the week, together with 7 lbs. of so bread, being in all 2 lbs. ¼ for each person by the day; a mu greater quantity than is used in England, even if the flour us in making puddings and pie crust is added.

### *French Sea Biscuit.*

The French sea biscuit is sometimes made by adding to ea 100 lbs. of flour, 10 lbs. of leaven older than that used for brea and a sufficient quantity of hot water to form a very stiff doug which requires to be kneaded by the feet. But, at present, is more usual to add to the flour half its weight of new leave and to make the dough thinner, so that it may be kneaded the hands for an hour.

The biscuits being weighed and flattened, are exposed in cool place until the whole are ready, and then baked. The ove is heated less than for bread, and as the biscuits are put in the are pricked in several places. The baking takes two hours. N salt is ever put into sea biscuits, that they may not attract moi ture.

These biscuits are very brittle, dissolve easily in the mouth or in soup.

### *German Bread.*

The German white bread, or semeln, is made of fine whi flour, and with yeast. The flour is mixed only three or fou hours before it is to be baked, as the sponge is only refreshe once, and sometimes not at all. The loaves are very small, th large simnel weighing only half a pound; these are circular, an joined two or three together; but the best simnel is made in tw ounce loaves, oblong, and joined five or six dozen together The large simnel are baked first, and remain in the oven abou half an hour; the small simnel is then put in: both are brushe over with water as they enter the oven; and some lighted sma coal being put at the mouth of the oven, some water sprinkle upon it, and the door shut, the crust acquires a fine brown co lour.

Scarcely any white bread made in Germany, except simnel, is made of wheat flour only. Lockewitz bread, esteemed next to simnel, is made by mixing dough made of wheat flour and yast, with an equal weight of dough made of fine rye flour and leven, kneading them together, and forming the dough into small loaves.

The German ovens are generally oval, with the door at one end, 10 or 12 feet from front to back, and the crown of the arch 5 or 6 feet high. As the ovens are so deep the loaves at the back cannot be arranged quick enough by the peel, and therefore young girls are employed to creep into the oven and arrange them. These oven-girls are enabled, by use, to bear the heat for several minutes. In Prussia the ovens are often floored with cast iron slabs: these might be advantageously adopted in the London flue ovens.

### *Wheat Starch.*

This is made from wheat by treading it in sacks in a current of water; the water being received in troughs is left to ferment, which decomposing the saccharine substances, renders the starch that is deposited, on standing, very pure and white: friable, easily pulverized, crimp between the fingers, without smell or taste.

### *Foreign Starch.*

This is made from the pollard and bran of wheat left after sifting away about half its bulk of the finer flour.

### *Potato Starch.*

It is prepared from raw potatos, especially those which have been spoiled by frost; very white, globular, crimp, friable, heavy: when held towards the light it has shining particles in it; dissolves in boiling water as easily as arrow root; 100 lbs. of potatos yield from 10 lbs. to 14 lbs. of starch; which is sold for arrow root, and German rice flour.

### *Potato Flour, Potato Farina,*

Is prepared from boiled potatos; it is scarcely soluble in water; and is manufactured into sago, saloop, maccaroni, vermicelli, semolina, and tapioca.

### *Potato Tapioca.*

This is made from potato starch; by boiling it before it is dried, stirring it to break it into lumps.

## PRODUCTS OF MILK.

The products of milk form most important manufactures almost every country, either in the form of butter or of chee although in the neighbourhood of great towns it is genera most profitable to sell the milk in its raw state. It is suppo that the same quantity of milk that will sell for 6*d.* will yi about 4*d.* if made into butter, and only 3*d.* if made into chee including the value of the pork, which is generally fed or f tened on dairy farms.

The milk of the cow is best adapted for making butter, a yields more than twice as much cream as ewes' milk; but t latter milk affords a larger proportion of curd than cows' mil and is, therefore, best adapted for making cheese. The ew however, is not worth milking, except where labour is ve cheap, in proportion to the price of butter and cheese.

The manufacture of cheese is best carried on in summer; t of butter in winter.

The average produce of a grass-fed cow is calculated at f gallons of milk by the day, from the cream of which about ounces of butter may be obtained; by feeding cows in the ho this produce may be increased, but the labour is also much creased.

### *Butter.*

The manufacture of this article depends greatly on the qu ty and quantity of the cream which can be obtained in the fi place from the milk.

Cows yield more milk when milked three times a day th when milked twice; whether they would bear milking oftene and whether the produce of butter is increased by this freque milking is not yet ascertained. The milk of some cows yie more cream than that of others; a cow which had been kept f several years amongst others, when sold to a person who ke only one cow, was found to yield no butter whatever, althou the milk appeared very rich. The first half of the milk draw from a cow which has missed having a calf that season is ve commonly sensibly salt, while the latter half is perfectly swe Turnips, cabbages, and some other kinds of food affect the ta of the milk, but whether this disagreeable taste is confined the first drawn milk is not yet ascertained. The cream yielde by the last half of the milking, if the udder is properly em tied, is not less than eight, and sometimes sixteen times as muc as that yielded by the first half of the milking, the average probably ten or twelve times that much. Water added to mil causes it to throw up a larger quantity of cream than if unmixe

the cream is of a very inferior quality. Milk carried to a distance before it is laid by for cream, or any other way shaken, yields much less cream, and also thinner than that which has not been agitated.

Cream which has not acquired the proper degree of sourness before it is churned, requires in summer long continued churning, and is generally soft, tough, and gluey; and in winter, the butter will scarcely be formed unless heat is applied, and then it is of bad quality, white, hard, brittle, and with very little flavour. The stroke in churning must be kept on regular, as a few hasty strokes will render the whole of the butter of scarcely any value. If the milk that drains from the cream is carefully separated, the cream may be kept for a long time, even many weeks, perfectly good. Butter washed, or only kept in water, is greatly debased in its quality, and will not keep good for any time. The quicker the milk turns sour the better.

These observations of Dr. Anderson and others show the method to be adopted in milking cows, and setting by their milk for cream. The cows should be milked close to the dairy door; as soon as half the milk is drawn from each cow it should be strained into a cream dish, which of course need contain only two gallons, and should never exceed three inches in depth. Wooden dishes are to be preferred, and leaden, tinned cast iron, or earthen vessels glazed with litharge, or red lead, totally rejected as injuring the cream and skimmed milk. The dishes are not to be scalded unless they contract some taint. New dishes, and those that have been scalded, should have some sour butter milk kept in them for twenty-four hours before the milk is put into them. The dishes to be placed on the shelves in the order the cows are milked, and which should always be the same, that the owner may estimate the value of each cow, and get rid of those that are unprofitable.

The cream is to be taken off at the end of six or twelve hours, according to the heat of the weather, and collected in a tub, having a spigot close to the bottom, that the milk that separates from the cream may be drawn off morning and evening. The cream of each milking is to be kept separate, and churned in sufficient quantity also churned separately. The cream is to be kept in these tubs until it acquires such a degree of sourness that it will yield butter by a moderate degree of agitation; which will, in general, require at least three days in summer, and a week in winter. The cream being churned and strained from the butter milk is to have the remains of the butter milk carefully squeezed from it, with as little working of the butter as possible, and then moulded into the form used in the coun-

try. Butter should not be touched during its making by t hand; but worked with the wooden hands used by the ch e mongers.

Such is the method which experiments show ought to followed in making butter, but the dairymen of different co ties follow several other modes by which they obtain butter various qualities.

In the counties around London the fresh cream butter made by letting the milk, in summer, remain in the p il n it is nearly cool before it is strained into the cream vats: h in winter time it is strained immediately, and a small quanti of boiling water added. In summer the milk does not rema in the vats more than twenty-four hours, and is skimmed eith before sun rising or after sunset: in winter it remains thirt six or forty-eight hours. The cream is kept in a deep pa and if a churning does not take place every other day it shifted daily into clean pans, and kept in a very cool plac A churning should take place, at least twice a week in hot we ther, and the churn remain during the whole time a foot de in water. If the butter does not come after considerable a tation, a spoonful of vinegar is added to each gallon of cre In winter time a little juice of carrots is sometimes added the cream when put into the churn, to give it the colour of M or Spring butter. The butter is immediately washed in ma different waters till it is perfectly cleansed from the mil , a then made up into rolls, called Epping butter or skittles.

In the west of England scalded cream butter is made by l ting the milk remain in shallow earthen pans for twelve hou in summer, and twenty-four hours in winter; the pans are th placed in stoves, made on purpose, and filled with hot embe where they remain till bubbles arise and the cream chan es i colour, when it is removed to the dairy, left for twelve hou more, and then skimmed from the milk, and put immedi te into the churn. Some scald the milk over the fire, but the the smoke is apt to affect it. Others put the cream into wooden tub and work it into butter by the hand. This butt is usually dished in half pounds for sale, the inside of the di being rubbed with salt.

In Lancashire and some parts of Cheshire the milk of ea cow is divided, the first drawn being set apart from the afte ings, or second drawing of the udder. The first drawn bei skimmed, the skimmed milk is used in the family, and th cream added to the whole of the afterings, which are n skimmed, but when sufficiently soured the milk and cream a churned together. To accelerate the souring the milk hou

s a fire kept in it, and the wooden milk dishes are not scalded, less they contract some taint; new dishes and those which ve been scalded are rinsed out with butter milk.

Butter is made on the breeding farms in the Highlands of otland, by letting the calves suck out half of their mother's lk, then driving them away and milking off the remainder. his butter is extremely rich, but as the farmers cannot be shed by straining the milk, the cows' hairs are usually mixed such large quantities with it, that it is not saleable.

When cows are fed upon turnips, the disagreeable taste of the turnip is ken off, both from the milk and butter made from it, by adding a tea-cupful a solution of saltpetre into every eight gallons of milk as it comes from the w.

The milk from which the cream has been skimmed, may either be made into eese, and the whey will afterwards do for store pigs; or, if the dairy is in e neighbourhood of a town where such articles can be sold, the skimmed lk may be made into sour cream and wigg.

In this case the skimmed milk is put over night into an open headed tub or all churn, with a spigot at the bottom, this is then put into a larger vessel, and t water poured into the space between them. In the morning, the vessel of lk is taken out, and the spigot being drawn, a thin part, called whig, runs t, and as soon as the thick part begins to run, the spigot is closed, and the ck part is poured into another vessel. When the operation succeeds prorly, the thick part is nearly half the milk, and seems to be as rich as real eam, from which it can only be distinguished by its sourness. It is eaten in otland with sugar, esteemed as a great delicacy, and usually sells at twice e price of fresh milk. Practice, however, is required to make this arle properly. It seems totally unknown in London and its neighbourhood.

In large dairies the labour of skimming the cream is endeavoured to be obated by churning the milk entire. In warm weather the milk is fit for churng in 48 hours, and it is usual to add a little cold water near the end of the urning to promote the separation of the butter. In cold weather the milk kept a day or two longer before it is churned, and boiling water is added to when in the churn. In very cold weather the milk must be kept in a warm ace to promote the coagulation, as the sooner this is accomplished both the tter and butter milk are the better, for when milk is long kept it contracts a sagreeable rancid taste.

Milk butter is not so rich as cream butter, but will keep much longer sweet: hen churned, as is most usual in large dairies, in a barrel churn, it is still oorer, but its quantity is increased sometimes double, as the milk is left quite xhausted. It is in this manner that the dairies about Epping make their butr at present; so that the butter that was the best is now the worst in the London market. The butter milk is used for feeding store pigs.

Where cheese is made from unskimmed milk, butter is sometimes made from ne whey, but this whey butter only serves for present use in the house, as it ill not keep more than a couple of days; and is indeed not worth making, s the whey fattens pigs very fast and makes delicate pork, but no good bacon an be made from pigs thus fattened.

For the purpose of preserving butter it is usually salted, and acked in barrels. The proportion of salt is generally an unce to a pound of butter. As the salt butter is brought to London from distant counties where labour is cheap, it is generally cream butter, and therefore, the London buttermen of-

ten wash the salt out of it and sell it for Epping butter, s n the dairies round London have got into the habit of churni from the milk. If a private family opens a barrel of salt b ter and consumes it but slowly, the butter should be cover with strong brine, to prevent the air from turning it rancid.

Thirty pounds of Lancashire butter, well salted with a double allow ce salt, were put into two mugs, and each covered with a pint and a half of bri After keeping in a cool cellar for 13 months, they were examined, and f to be perfectly good, two years and seven weeks having elapsed, the mu were broken by an accident, and the butter being found to be perfectly goo the salt was washed out, and the butter sold for fresh butter in the Liverpo market.

A far superior kind of salted butter, called Udney butter, made by using for the seasoning a mixture of two pounds salt, one pound of saltpetre, and one pound of sugar beat we together. This butter does not taste well until it has stood least a fortnight after being cured, but it then tastes rich, ma rowy, and but slightly salted.

For exportation to hot climates, butter ought to be clarified before it is s ed. For this purpose it is put into a lipped vessel, and placed in a vess water which is to be gradually heated until the butter is melted. It is to kept melted for some time to allow its mucilaginous particles to settle; clear melted butter is then to be poured off from the dregs, and when s ciently cooled is to be salted. This clarified butter is paler than the fresh, a it acquires nearly the consistence of tallow.

Butter is sometimes preserved with honey as a delicacy. It is first clarifi and being poured off from the dregs, an ounce of firm honey is added to ea pound of butter well mixed with it. This mixture will keep for years witho becoming rank.

## *Cheese.*

Cheese is the curd formed in milk when coagulated by th addition of certain substances, pressed and dried for use.

There is scarcely any article in which a greater variety appearance and taste exists; the inhabitants of almost every va ley on the face of the globe make a different kind of cheese.

Milk is usually manufactured into cheese when the farms ar too far distant from a large town for the milk to be sold fresh or even as butter, it being the least profitable manner of usin it.

*Cheese from new milk fresh from the cow.* To this belong the best making, or one meal Gloucester cheese, of which tw sorts are made, thin or single cheeses, about 8 to the cwt., an thick or double, about 4 to the cwt. The single cheese i mostly made from April to November, the double only in May June, and the beginning of July. When, however, the cow are well fed, good cheese may be made in the winter; but, i

neral, the milk in the winter is not rich enough, and even e cheeses made late in the summer do not acquire sufficient mness to be marketable in the spring.

The liquid employed throughout England for coagulating ilk is called *rennet*, *runnet*, or *steep*. A calf's stomach bag, maw, is washed clean, and salted thoroughly, inside and t. In two or three days, the salt left on it having run, it is ng to drain for two or three days, re-salted, put into a jar, d covered with paper, pricked with pin holes. It may be used a few days, but is best kept for 12 months. When prepared r use, a handful of sweetbriar leaves, of dog-rose leaves, and of amble leaves, as also three or four handsful of salt, are boiled a gallon of water for a quarter of an hour; and when quite ld the salted maw is added, as also a lemon stuck round with quarter of an ounce of cloves. The salt must be in sufficient uantity that some may always remain at bottom; and the steep ust be scummed as often as is necessary.

The milk warm from the cow is first coloured, by rubbing own on a stone some annotto, about 1 ounce for each expected vt. of cheese, and mixing it with the milk. The rennet is hen added, about one-third of a pint to 50 gallons of milk. s soon as the milk is curdled, the whey is strained off, the urd broken small, put into a vat, and pressed gently for two ours, then turned, pressed again for six or eight hours, again urned, rubbed on both sides with salt, pressed again for twelve r fourteen hours, and finally dried on a board, being turned very day. In large cheeses, the sides are pierced with iron kewers to allow the whey to escape during the pressure, which s very moderate, upon a medium only 1 cwt. and a ½ dead veight.

Gloucestershire has hitherto been the principal seat of this manufacture; but North Wiltshire begins to take the lead. Chedder cheese is of this kind, and esteemed the choicest sort, but the quantity made is very small. The Gruyere cheese of Switzerland is also of a similar kind; like Chedder cheese, it is full of eyes, filled with rich limpid oil, which is not rancid; in flavour, this cheese is decidedly superior to any of the English species; the rennet is probably made with an infusion of aromatic and sweet herbs, instead of the leaves used in England.

For lyings-in, christenings, and other festivals, fancy cheeses are made, such as truckle cheeses or loaves, brick bats, hares, rabbits, dolphins, and the like; these are mostly made in Wiltshire. Green cheese is made by steeping over night in milk, some sage, with half as much marigold leaves, and a little parsley, and then mixing the curd of this milk, with the curd

of white or ordinary milk: this is also chiefly made in W shire.

*Cheese made from the milk of two or more milkin mixed together.* The Cheshire cheese is of this kind; in gene only two meals or milkings are put together, but sometim when the milk is scarce, three, four, or even five meals. T cold milk, being creamed, one-third or one-half is made sca ing hot, and one-half is then added to the remainder of t cold milk, which has, in the meanwhile, been coloured by piece of annotto, tied up in a linen rag, soaked all night warm water, and then well rubbed into the milk, until the b has given out all its colour. The other half of the scald milk is mixed with the cream, and both the parcels added the milk warm from the cow; this melting of the cream, as is called, is thought to be the best method of uniting two more meals of milk.

Rennet, made with plain brine only, in which the maws ha been soaked for 24 hours, is immediately added, and when t curd has come, it is cut into pieces by a knife, the wh skimmed off, the curd broken smaller by the hand, and so salt mixed with it. Being vatted, it is pressed for about hour, taken out, and left to stand in hot whey or water for hour or two to harden its skin. The cheesling is again pres for a couple of days, but it is often taken out, skewered, a turned. The cheese is then either left in brine for seve days, turning it once a day, at least, or it is turned at le twice a day for three days, and the upper surface covered wi salt. After this, salt is rubbed upon it daily for eight or t days, and it is then washed and dried. A cheese of 60 lb takes in all usually 3 lbs. of salt. When dried, the chees are smeared every day for a fortnight with fresh butter, whic is well rubbed in; and as long as they are kept they are turn every day, and butter rubbed in three times a week in summe and twice in winter. The consumption of this cheese dim nishes very rapidly.

The Dunlop cheese of Scotland is also made from the ev ning meal of milk, warmed, mixed with the morning meal, an the rennet added immediately; no colouring is used. Th whey as it gathers is laded off, the curd drained, and eve pressed with a light weight. It is then cut up by a knife wit three or four blades, salted, mixed by the hand, and presse with a heavy stone of 10 or 20 cwt. being frequently take out and examined. When all the whey is pressed, the chees is taken out, turned, and rubbed frequently with a coarse cloth The usual size is from 20 to 60 lbs. in weight.

In Ross-shire some private persons bury these cheeses separately in the shore below high water mark, to make them become blue, moist, and rich tasted.

*Cheese made by adding cream to new milk*, or *cream cheese.* this kind is Stilton cheese, the cream of the night's milk added to the morning's milk, along with the rennet. The curd is not broken, but put into a sieve to drain, and very gently pressed; when the cheese is sufficiently firm, it is put into a wooden ring, and kept on a dry board. These cheeses are chiefly made in Leicestershire, and weigh from 6 to 12 lbs. They are not saleable until decayed, blue and moist, which requires about two years' keeping. A little wine is sometimes added to the curd to bring forward the blueness earlier: others place the cheeses in buckets, and cover them with horse dung. A thicker sort of this cheese is called Cottenham cheese.

The Lincolnshire cream cheese, called in London new cheese, is made in the same manner, but is little more than an inch thick. It is pressed with a two pound weight, and sold when only a few days old, to eat with radishes or salad.

York cream cheese is thus made; the curd when turned out of the sieve is cut into a square cake or tile, placed on rushes, covered with them, and pressed with a half pound weight. It can only be kept in a cool place, and for a few days: the whey left in the curd becomes acescent, and this acidity is agreeable to some palates.

*Cheese made from new milk, mixed with skimmed milk.* The half covered milk Gloucester cheese is of this sort; they are usually marked with a heart, to distinguish them from the whole covered milk cheeses, and are often called Warwickshire cheese: it sells about 10*s.* by the cwt. less than the Gloucestershire.

*Cheese made of skimmed milk only.* This cheese is only made in those districts where butter is the chief object of the dairyman; and the milk is used after it has been skimmed three or four times; as in Essex and Suffolk. The English cheese of this kind has seldom a good flavour; but although it is generally nearly as hard as horn, it is much easier of digestion than some of the soft cheeses. The Dutch round cheeses which belong to this class are of a fine flavour; and the Parmesan cheese of Italy, is, by many, esteemed to have the finest flavour of any cheese, not even excepting Gruyere.

Parmesan cheese is made of two meals of skimmed, the evening's meal having stood about 18 hours, and the morning's about six hours. The mixed milk is heated in a copper boiler to 82 deg. Fahr. a lump of rennet, the size of a walnut, for 66 gal-

lons, is tied up in a cloth, and worked through it into the wa milk, which is then turned from the fire, and left for an hou coagulate; after which the curd is stirred up for another ho broken much smaller by a stick stuck all round with wire, left to settle. Part of the whey is taken out, the boiler tur again over the fire, one-fourth of an ounce of saffron added colour it, the milk made nearly to boil, keeping it well stirr and occasionally examining some of the curd between the fin and thumb. When the curd feels sufficiently firm, the boile removed from the fire, three-fourths of the whey ladled o and three or four gallons of water dashed against the boiler cool it. A cloth is slid under the curd, and it is placed in a to drain; it is then put into a hoop and pressed with half a c for an hour. The cloth is then taken away, the cheese pla again in the hoop for two days; after which the two cheeses placed one on another, changing them every other day, fo month in summer, and six weeks in winter; during which riod they are sprinkled over with salt, at each time of turn them. The cheeses are then scraped clean, turned every d and rubbed frequently with linseed oil to keep off insects: t are never sold until six months old.

In some imitations of Parmesan cheese, ewes' or goats' r is added to that of the cow; or the cheese, as at Roquefor made entirely of ewes' milk.

*Cheese made of whey and butter milk.* After the curd Parmesan cheese is removed from the boiler, all the whey added to the butter milk of the morning's meal, which has b churned in the mean while, an acid added to coagulate it, thus a cheese called maschopino is made.

The fatness of cheese cannot be ascertained by its appearan but by toasting it, as some cheeses, apparently fat, dry up heat, while other dry and hard cheese when toasted becon fat.

A cow ought to produce her own weight and value in che by the year.

Four hundred and fifty gallons of cows' milk ought to p duce four hundred and thirty pounds of cheese, ewes' m would produce a greater quantity.

The milder sort of these cheeses are used for food, as Gloucester and Warwickshire cheese; but the highly salted ki as Cheshire cheese, are mostly used in small quantities to flav bread, and other food. The power of promoting digestion tributed to cheese, does not belong to any of these cheeses, to the ammoniacal cheese, which is totally different.

### *Ammoniacal Cheese.*

The fromage de Brie may be taken as an example of the fo-n cheeses, in which the cheesy matter is so totally altered t it is no longer acid or neutral, but is become putrescent and moniacal, so as to emit ammoniacal gas, when rubbed with of tartar.

The milk warm from the cow is strained, a very small por-n of rennet is added to it, and it is left for twenty-four hours. e curd is put into a hoop and drained for several days in a ar; it is then taken out of the hoop and exposed to the open whose temperature is about 59 or 60 deg. Fahr., and is ned every other day, and sprinkled with salt. When dry s returned to the cellar, placed upon hay, and occasionally ned until it has become perfectly mellow, and as it were pu-l.

The cheeses of this kind are generally made very small; netimes only a few ounces in weight, so that half a cheese is ordinary service for a single person. Some are made like all brickbats, others globular like wash balls. Only the mid-is eaten.

The digestive qualities usually attributed to cheese by physi-ns, probably belongs only to this kind.

### DISTILLED WATERS.

Some of these are intended for medical purposes, mostly as hicles, others for perfume. In respect to medicines, no great e is usually judged necessary, the herb just as collected, thout any preparation of decayed parts, or accidental mix-e of dirt or other substances, is added to the water, distilled a short necked wide still as quickly as possible, and 2 drams spirit of wine, or even more, added to each pint. Many not even take this trouble, but rub a drop or two of the , with a little magnesia, and add it to common water, or ute the oil with ten times as much spirit of wine, and add, hen it is wanted, a few drops of this essence to the water or her vehicle.

But for perfumes, as rose water, elder flower water, &c. more e is requisite, as the buyers must be pleased with their smell d appearance; hence the herb, &c. must be carefully picked, d the water as carefully distilled in a high necked still, in or-r that no part of the infusion may be thrown over with the stilled water, as this would render them liable to become mo-ery in a short time: if a superior article is required, the wa-

ters must be re-distilled by a gentle heat. Waters which have acquired a burnt smell in the stilling lose it by freezing.

These waters must also be kept in a cool place, covered over with paper, pricked with pin holes, for four months, to get rid of the herbaceous smell of fresh distilled waters. Distilled waters may be prevented from turning sour by adding a little calcined magnesia to them; and those which have begun to be spoiled may be recovered by adding to each pint, a grain each, borax and alum. A drop of muriate of gold added to these waters shows whether they contain any oil, by forming in that case, a fine metallic film on their surface.

These waters are now more commonly distilled from the essential oils of the plants, than from the plants themselves. The price of the oil, combined with that which can be procured from the water, determining the quantity to be added.

The distilled waters usually made in England are rose water, mostly from the Barbary oil of the evergreen rose, and elder flower water, from the flowers themselves.

The distilled water of silver weed, or wild tansey, is used by the French in dressing gauze, and this is the only instance of distilled water being used in the arts.

## INFUSIONS, DECOCTIONS, AND EXTRACTS.

These are solutions of the proximate principles of vegetables and animals in water; either liquid or boiled down to a solid consistence.

### *Tea.*

Although the consumption of Chinese tea is greater in England than in any other country, yet no where is it made so badly or on worse principles.

To have good tea the whole quantity of boiling water intended to be used should be, as is the case in all infusions, poured once on the leaves, previously bruised, left to stand until sufficiently impregnated, then strained off, and the auxiliaries, milk cream and sugar, added.

A still better method to preserve the flavour of the tea is, to pour the requisite quantity of cold water upon the bruised leaves, and put the vessel into a pan of water boiling on, or beside the fire, until the tea is sufficiently heated to be poured and drank, observing that if much milk, or the like is added the tea must be made so much the hotter, that they may not cool it too much. This is the usual method in China.

A variety of British plants have been proposed as substitutes for Chinese tea, but they do not possess the quickly diffusible

mulus of the real tea. Besides, they are used too fresh, the inese keep their tea two years before they use it; and from ir cheapness are employed in too great proportion to the ter.

The usual consumption of tea for a man and his wife in Eng- d is about a quarter of a pound of tea, and a pound of white gar weekly; this will give half a quarter of an ounce of tea, d half an ounce of sugar for each person at each meal.

### *Coffee.*

This is more drank on the Continent than in England: in- ed, that drank here is a mere slop compared with the foreign, hich is, however, of very different strengths, even so far as to drank unstrained, and of sufficient thickness for a spoon to nd upright in it for a short time.

The usual allowance for coffee in England is about one-fourth an ounce for each person; the Dutch and Germans allow out three times as much. It was formerly boiled up several mes, whole black mustard seed added to increase its stimulant ality, and then clarified with an egg. At present it is a mere fusion, the hot water being only run through it, and the infu- on heated again.

Late experiments have shown that the best way of making offee, is to put the ground coffee into a wide-mouthed bottle ver night, and pour rather more than half a pint of water upon ch ounce and a half, to cork the bottle, in the morning to osen the cork, put the bottle into a pan of water, and bring e water to a boiling heat; the coffee is then to be poured off lear, and the latter portion strained; that which is not drank mmediately is kept closely stopped, and heated as it is wanted.

Rye, roasted with a little butter, is much used in England as offee, by the name of economical breakfast powder. On the ontinent, about one-third of succory root roasted is added, to iminish the expense of drinking pure coffee.

A number of infusions and decoctions are made by the apo- hecaries, but they cannot be considered as manufactured arti- les; neither can the infusions of litmus, and the like, which re used as tests.

### *Cake Glue.*

The materials from which glue is made are the shavings cut ff from the skins in currying the various kinds of leather, the eather packages of indigo, aloes, and other commodities; also ide ropes, ears and feet of hides preparing for tanning. All of hese are soaked for a fortnight or three weeks in pits of lime

and water, fresh lime being added every week; after which th are rinsed in water to get rid of the lime, and spread on ment till the superfluous water is dried away.

These materials are then boiled in water until they are tirely dissolved, and that the liquor dropped upon a cold s becomes solid, when it is run off into an iron pot warmed heating some water in it, and there kept quite hot for fo hours to settle; after which it is run off into the moulds, whic are shallow wooden boxes, the sides being only the intende thickness of the cake in height. The liquid glue is ladled int these boxes through a horse-hair sieve. After being in thes boxes and a cool place for eighteen hours, the glue is sufficien ly firm for drying on the net. A wetted knife is run round th edge of the box to loosen the cake, and the box turned over an let fall upon a table to separate the mass of soft glue, which i then cut by a copper wire stretched by a frame in square cake and these are dexterously taken up by a knife and placed o nets stretched in a wooden frame, and these frames are suppor ed by stages to allow the glue to dry.

In hot weather, the glue dries too quick, and is apt to crack in cold weather it freezes; moist weather not only retards th drying, but makes the cakes stick to the nets; and if it is al hot, even to run through them; so that the cakes are sometim obliged to be dissolved and moulded again.

When the cakes are sufficiently dry, which in moist weathe frequently requires the use of a stove, they are glazed, by b ing dipped, one by one, in boiling water, and then rubbing ther with a brush; after which, if the weather is not very fine, the are placed on frames in a stove, until sufficiently dry to be packe up for sale.

The remains of the material left in the boiler have a little water added to them, and are then taken out and pressed. Wha liquor is obtained from them is added to the water in the boiler and used in the next operation.

Attempts have been made to improve the manufacture of cake glue by putting in a larger quantity of materials in proportion to the water, and drawing off the liquid as soon as it is sufficient ly charged to set when cooled: to add hot water to the materials still in the boiler, and again draw this off when sufficiently charged; and to add a third time fresh water to the remains. By thus dividing the products, the first drawing off, which has not felt much of the fire, affords a light-coloured clear glue, the second a dark-coloured glue, rather opaque, and the third a red dish muddy glue. This method has been obliged to be given up, because workmen prefer dark-coloured to transparent glue.

When cake glue is to be used it is broken to pieces and aked for a night in its own weight of water.

### *Flemish or Dutch Glue.*

The material is the same as for English glue; but they are tter rinsed in several waters, and even left to soak some time, at they may require less boiling. The boiler is run off twice, e liquid not being so much boiled down as usual, and the kes are made very thin, that they may appear transparent.

### *French Glue.*

The boiling of the materials is continued a long time with a nall fire, and the liquid carefully scummed. When the mate- als are dissolved, the liquid is made to boil, and then drawn f into the lower caldron, about two grains of alum to the pint added to clear it, and after an hour or two it is moulded. his glue is transparent and very brittle.

### *Hat-makers' Glue.*

The materials from which this glue is made, are the tendons nd small bones of the legs of oxen and horses; as much mus- e is left with the tendons, the glue remains soft, and absorbs ne moisture of the air. It is brown and opaque. The hat nakers prefer it as not rendering the felt brittle.

### *Size.*

The materials for this kind of soft glue are the skins of rab- its, from which the hair has been taken for making hats, old gloves, the trimmings of parchment, as also parchment records r manuscripts, obtained from the porters of the register of- ices or public libraries.

The boiling is made with a small fire that the liquid may not become coloured, and there is added about twice as much water as in making the cake glue; when sufficiently boiled it s drawn off into barrels.

Size is also made from the same materials as cake glue, only the first of the boiling being taken.

The single size is very soft, but for some purposes double size, of a firmer consistence, is made.

### *French Bone Glue, Gelatine Brut,*

Is made from the skulls of oxen, the spongy insides of ox horns and the ribs; by washing them, soaking them in an equal

weight of weak muriatic acid, at 6 deg. Baumé in the win and 5, or only 4 in summer, for about ten days; pourin the acid, soaking them afresh in acid at only 1 deg. Bau for a day and night, steeping them in water for some hou renewing it five or six times until all the acid is washed ou and finally steeping them in a very weak solution of subcarb nate of soda. 100 lbs. of bones yield about 25 lbs. or 27 lbs. gelatine brut: which is used for making carpenters' glue, the fat in the bones gives it a bad taste, and renders it unfit f soup.

### *Portable Soup.*

Break the bones of a leg or shin of beef, put it into a dige tor that will merely hold it, cover with cold water, boil it ge tly for eight or ten hours, strain, let it cool, take off the fa pour into a shallow stew-pan, add whole black pepper a qua ter of an ounce, boil away to about a quart, pour it into a small stew-pan, and simmer gently till it is reduced to the thic ness of a syrup, then either pour it into small upright jel pots, with covers, and when cold paste the joints over wi paper; or pour it out upon flat dishes, to lie about a quarter an inch deep; when set, divide it in pieces and dry them. shin of beef of 9 lbs. produced 9 oz. of portable soup, and lbs. ¼ of meat fit for potting: no other part yields so much.

### *French Portable Soup, Gelatine Fin,*

Is made from the skulls, blade bones, and shank bones sheep, the ends being cut off, and the bones cut down the mi dle to remove the fat, steeping them in muriatic acid, as th gelatine brut of ox bones, then in boiling water for a few m nutes, wiping them carefully, drying them, shaking them to gether in a bag to remove the internal pellicle, cutting the across, or into dice to disguise them, and finally dipping the in a hot solution of gelatine to varnish them. Used to mak soup, keeps better than the cakes of portable soup: and whe less carefully prepared it is used also to make carpenters glue for fine work. The muriatic acid obtained by distillin salt with oil of vitriol in iron cylinders is less fit for this pu pose than that of the manufacturers of subcarbonate of soda, a being apt to give the gelatine a bad taste.

## FERMENTED LIQUORS.

All fruits consist of the following principles: water, sugar a peculiar combination of sugar and extract, called the swee

nciple by the French, supertartrate of potash, malate of pot-
, and malic acid, superoxalate of potash, extractive matter
logous to mucilage, vegetable gelatina, tannin, a principle
flavour, and a colouring principle.

The essential ones to the making of wine are the tartaric
d, sugar, or the sweet principle, extract, and water; and
se which are useful, without being indispensable, are flavour,
nin or astringency, and colour.

Tartaric acid, or its combinations, is especially indispensa-
: and hence it is that the grape, which contains it in large
ntity, produces wine; when the apple, and other fruits
ich contain the malic acid, produce cider.

Where malic acid is also present, the quality of the wine is
. Sugar must be considered the fundamental element, and
that from which the alcohol is chiefly derived. Thus the
st saccharine grapes produce the strongest wine.

The chemical nature of the extractive matter is not known;
it is supposed to contain azote, as this is the produce of
mentation. Yeast, or leaven, contains the extractive prin-
le in great abundance, and hence its power in inducing fer-
ntation in a solution of pure sugar. All vegetables contain
and it is most abundant in those juices which gelatinate in
ling. It is found in the grape, and it is thus the natural lea-
n of wine, whether existing in a separate state or united to
gar in the form of the sweet principle. Water is a much more
ential ingredient than would at first be suspected. If over
ndant, it is difficult to prevent the produce from running to
e acetous stage; hence weak wines become sour. If deficient,
is difficult to establish the fermentation; and hence sweet
nes. Thus, also, sweet wines are ensured by drying the
apes, or evaporating their juice, both common practices in
e wine countries. Colour must be looked on in the light of
ornament, and is found in the husk of the grape. So is the
nnin principle, which occasions astringency in port wine. Of
e principle of flavour chemistry knows nothing; it seems of-
n the produce of fermentation, as in claret and Burgundy
nes: in those of Frontignan and Muscat, it is the natural
vour of the fruit.

In fermentation, the superfluous extract or leaven is sepa-
ted in two forms, that of yeast and lees; and these will ex-
te that process in fresh solutions of sugar, or renew it, or
ntinue it, in the mixture whence it was separated; whence
cking and fining. There is, however, one important diffe-
nce between the natural or original, and this artificial or se-
ndary leaven. The latter is soluble in hot water, and not in

cold; and hence it is separated in fermentation. By r
this separated matter to wine in the course of fabricatio
fermenting process is prolonged, or the wine rendered d
by skimming, and fining, and racking, the process is chec
and hence the application of these practices to sweet wi
The *rolling* of wine, or returning on its lees to *feed*, is h
understood; and hence also the improvement which cer
wines experience in long voyages. But the same princ
and process which improves Madeira destroys Burgundy,
the reason must now be obvious. The theory of rack
fining, and sulphuring, is hence also apparent; and, of the
phurous acid, it has a property to combine with the lea
and form an insoluble separable compound. It is thus th
checks fermentation. Hence, also, it is that sweet wine
not turn sour; their leaven has been expended. Thus also
may see that the process of fermentation is not an unmana
ble and a precarious one; but that the essential ingredients
in our power, and that we can modify them to the desired re

If it has been stopped prematurely, it may be renewed
fresh leaven; if in excess, it may be checked or suspended.
thus it is too, that dry wines, and fined wines, and wines in
tles, are durable, when they would perish in the cask.

The acid was shown to be also essential to the produ
wine. Mere extract, or leaven, and sugar, produce beer,
wine. Tartaric acid cannot well be in excess in that compo
in which it exists, viz. the supertartrate of potash; becau
is a salt of difficult solution, and the superfluity is precipita
hence the tartar of wine casks; hence, also, the crystals w
are seen, in cold weather, to float in Madeira wine. A p
it is converted into malic acid; hence the peculiar propertie
some wines; hence also the practice of liming the vats, o
sprinkling the grapes with lime in the manufacture of She
wines; whence they acquire that peculiar dry and hard t
which distinguishes them from the wines of Madeira.

As the tartaric salt adds to the fermenting power of the fl
hence we explain the facility with which the juice of gr
grapes runs into fermentation when compared with ripe o
the immature fruit containing a much larger proportion of
salt than the mature. Thus also those wines continue to
ment longer, or to retain the power of fermenting; and he
the vivacity of Champagne wines, the most effervescent ki
of which are made from half ripened fruit.

The temperature of 54 deg. Fahrenheit, is considered
most favourable to this process. Hence, also, it is that wi
which have ceased to ferment, re-commence in spring;

ce, one of the processes essential to the manufacture of mpagne wines; namely, that of watching the spring fer- ntation, and bottling the wines in this stage.

The volume of the fermenting fluid has a considerable effect the process; a few days are sufficient to complete it when quantity is large. When small, it is difficult to establish, tedious in the progress, and the results are also diffe- t.

That substance, which exists in yeast, has also been found the disengaged gas, partly, it is said, in the form of ammo- ; and hence, possibly a nauseous ammoniacal taste, well wn in bad wines, and very remarkable in those of the Cape Good Hope.

The colour of wines is also produced during the fermenta- n; the red appears to be a substance analogous to resin, solu- in alcohol; and thus its production is accounted for. Hence, ite wines may be made from red grapes, by excluding the sks; hence also, red wines are often astringent; because the nin also lies in the husk. Thus also, in Champagne wines, red are generally inferior.

Thus, when all the necessary circumstances are present, the cess goes on till the produce is pure wine, or a compound alcohol, water, acid, colour, vegetable extract, and sugar. r although the two latter are said to be destroyed, there almost always a minute portion of both remaining; the mer rendered very sensibly, in some wines, by the skinny tter which they deposit on the sides of the bottles. In a hilar manner, it happens, that a portion of sugar continues ached to the wine for a long time, though it is not always sible except to a fine taste. Thus, it is perceptible in claret, d even in Madeira, which are among the driest of our wines. is often very sensible in Port; and, when in excess, is com- nly the mark of a bad wine.

It is the gradual conversion of this sugar, the chief operation t goes on in bottled wines, which is the cause of the change hich these undergo. This process often requires many years r its completion; this is the case in the clarets of Chateau argaux, and other Bordeaux wines; and the same process deed takes place, to a greater or less degree, in Madeira and e other strong wines. In these cases, it is a cause of im- ovement; the wine becoming more perfect under this last dious fermentation; in others, however, it is mischievous: d hence the destruction of many wines. Thus Champagne destroyed, and often very quickly: thus Burgundy also is sily ruined; and thus, even our Port is not a very durable

wine, though the destruction is here accelerated by the in mixture of brandy used in this particular manufacture.

By the same considerations we can account for the benefit which M wines receives in a hot climate, or in a hot cellar. The effect of and in the case of a sea voyage, united to the agitation, whose acti sidered before, is that of accelerating the imperceptible fermenta thus ripening the wine sooner than would have happened, in a lo ture and at rest. It is a mistake to imagine, that this is peculiar to or that it is the only wine which can be benefited by this treatment. same for all the Spanish wines, for Sherry and for Port, and it is a the better and safer wines of France, of those of Hermitage and the Claret becomes drinkable in a much shorter time in a warm than in a cel lar; and that is equally true of many more of these wines. But that some will bear, others will not; and thus many of the wines of France, from admitting a high temperature, can scarcely be preserved even in a one. As to Port, it is a useful piece of knowledge to be aware, that it speedily be rendered aged by heat. And in this case it deposites its colour, assumes the marks of old wine to the eye as well as to the palate. One will thus do that for Port which might have required five or six; but the pe of its entire duration is consequently shortened, as might be expected. effect of heat is indeed such in this case as is suspected by few. In A it is a well known practice to boil Madeira, or to heat it to the boiling te rature, and the effect is that of rendering it good and old wine, when p ously harsh and new. The same practice is applicable to Port. If n tled wine be exposed to the sun, it begins shortly to deposite, and im flavour; and even the rawest wine of this kind may, by heating it in h be caused, in the course of a day, to assume the quality which it woul have had until after many years of keeping.

In Hock, it would seem as if every atom of sugar had nished, and yet the durability of that wine appears to be less. If that is not absolutely the case in Claret and Made still these are very durable wines; the most so, after Hock least of the dry class. None of these, when of a good qu ty, ever run into the acetous fermentation.

When all the favourable circumstances above stated are p sent, the fermentation begins and passes through its regu stages till there is produced wine, perfect and dry, if the su has been thoroughly and accurately proportioned to the ot ingredients; sweet, if it has been in excess; and acid, as Hock, when this substance has been in undue proportion to other ingredients. The unfavourable circumstances must sought in the temperature, or in the quality of the fluid. T juice of the grape rarely labours under any defect but the w of sugar, arising from a bad variety of this fruit, from a season, or from imperfect ripening. In the latter case, how ver, there may be added to defect of sugar or excess of wat an excess of acid and of extractive matter.

In the wine countries the defect of sugar is remedied by ferent expedients. In some, sugar or honey is added to

ce, or must; in others, a portion of the juice is evaporated
l added to the rest; and sometimes, all the juice is boiled be-
e it is submitted to fermentation.

To gain the same ends, it is a practice in many countries to
y the grapes partially, by suffering them to remain on the
ne; but this is chiefly resorted to for sweet wines, as in the
se of Cyprus, Tokay, Lipari, and others. The other expedi-
t for increasing the proportion of sugar in the juice is by plas-
r of Paris, or gypsum, not an uncommon ingredient; and
s effect, as well as that of absorbing and destroying super-
ous acid, is also partially attained by the use of lime.

The management of the fermentation, supposing the fluid to
perfect, is regulated by the intended nature of the wine. If
eet wine is desired, not only must the proportion of the
ter be diminished by one or other of the means above men-
ned, if necessary, but the proportion of extractive matter
leaven must be reduced, to prevent it from running to the
timate stage, and producing a dry and strong wine. In this
se, the yeast is separated as fast as it rises by mechanical
eans; as by fermenting in full casks in such a manner that it
ay be continuously ejected at the bung hole as fast as it is
rmed. Should the reverse be desired, or a dry wine be the
anufacturer's object, the yeast is suffered to remain on the
rface in the vat, that it may be continually returned into the
quor by the internal agitation, or else it is stirred, or rolled
a cask, or in the vat, so as to protract the fermentation. Last-
, if the wine is to be brisk, to retain carbonic acid, as in the
ines of Champagne, not only must the proportions of water
d leaven be increased, but the fermentation must be con-
icted in vessels partially closed, and these also must be fully
osed before the fermentation is completed.

Wines may be divided into four classes: the sweet and strong; the dry and rong; the delicate and light, which are generally weak compared to the for-er; and the effervescent or brisk. Malmsey, Tokay, Frontignan, are exam-es of the first, and the second are peculiarly familiar to England. Hermitage olds an intermediate rank, as does claret, between these and the third class; which the lighter Burgundy wines, the white wines of Greece, and those of e Rhine and the Moselle, may be considered pure examples; and, of the last, hampagne is almost the only one that deserves to be named.

If, therefore, the intention is to make either a strong sweet wine or a strong y one, the fermentation is commenced in an open vat. But, in the former se, it is not suffered to remain there long, as it is in the latter. For the driest ines, or for those which are manufactured for distillation, the fermentation is lowed to expend itself in the vat, and the wine is not tunned till it is made; e completion of the process merely, or the final solar fermentation, being re-rved for the cask. In the sweet wines, on the contrary, it is soon removed om the vat to the casks, that it may be more in the operator's power to sus-end the process, and thus to prevent the annihilation, or total conversion, of e saccharine matter. In the third class again, in the highly flavoured wines, which Burgundy may be selected as an example, the fluid is only suffered

to remain a few hours in the vat; from six perhaps to twenty, that period va ing according to the state of the temperature, the particular quality of the ju as to goodness or strength, and the other views of the manufacturer. T done to prevent the dissipation of the flavour, which would be injured, if destroyed, by an open fermentation. The same practice is followed for t wines of Champagne, though there is here little flavour to preserve; the pu pose being, in this case, to secure the power of checking the fermenta pressure, so as to retain the wine in a low stage of this process, and thus to cure a supply of mixed, or combined carbonic acid, at the period of use drinking.

If, after the wine is made and tunned, it were suffered to g on fermenting, it would, in many cases, be destroyed. Thi it has already been seen, does not easily happen in the swe wines, where a large portion of the saccharine matter remai unchanged, though even these are not absolutely exempt. N does it very easily happen in the stronger dry wines. Yet does happen to all, and is almost inevitable in the light sti wines, and in the brisk ones, whatever the strength or swee ness of the latter may be. Champagne would quickly becom vapid, Burgundy would become stale and sour, and clar would become vinegar. For though the natural progress is su posed to be from the vinous to the acetous stage of fermen tion, there are phenomena in practice which show us that w are yet imperfectly acquainted with the exact nature and var ties of fermentation. Champagne, for example, becomes m cilaginous and flat; while, though Burgundy becomes acid, is scarcely possible to make it pass to the exact state of vi gar.

The processes of racking and mechanical separation just d scribed, are all intended to separate this matter: and whenev the wine remains turbid, it is always in danger, because t fermentation may at any time be renewed. But often the operations are insufficient to disengage all the leaven or lees; much of it not only continues mixed, so as to produce the tu bid state, but the extractive matter itself, which has not bee brought to this insoluble form, remains combined with t fluid.

The merely turbid state is remedied by the process calle fining, which precipitates all the insoluble or disengaged le and leaven that will neither subside nor rise; thus removi one part of the hazard, besides communicating that brightne and beauty which is demanded in all wines. That brightnes therefore, is more than a beauty, since, without it, there is n security,—at least in the finer and lighter wines. Various su stances are used for this purpose, and the action of many them is very obscure. The mechanical substances are sand a gypsum, both of which have the property of precipitating t insoluble matter; while the latter also absorbs water. Beechwo

ips are sometimes used for the same purpose; but the mode which these act is not known. But the matters chiefly in e are chemical ones, gluten and albumen. Of the latter, eggs d milk are both used; but the former are preferred. Of glun, isinglass alone is used; for, from some causes hitherto unscovered, the gluten of terrestrial animals, or common glue, oes not produce this effect to the same extent that it is obtain- by the glue of fishes. It is also usual to adopt albumen for e white wines, and gluten for the red; as the former is found precipitate much of the colour from these last. The proortion used is very small, an ounce of isinglass being sufficient r a hundred gallons. To these chemical matters we might ave added starch, gum, rice, and blood, but they are very ttle used. The action of the albumen appears more mechacal than chemical; becoming coagulated, and then entangling e dust, if it may be so called, which is suspended in the fluid, the same manner as it would purify muddy water. In the se of the gluten, however, a new chemical combination is rmed with the tannin of the wine; and the produce is that ell known substance resembling bird-lime, which is the basis leather. Hence, also, fining diminishes the astringency of d wines.

Presuming that one of these substances has been introduced, the fluid is rongly agitated and suffered to repose till clear, when it is again racked into fresh cask. It is found very important to select for this purpose dry cold eather, and, as is particularly remarked, north-east winds. From some mysrious cause, in close weather, and fogs, and southerly winds, the precipitated atters rise again, and defeat the objects of the operation. The other precauons are those of using a syphon instead of a cock, as affording greater secuty; or, what is now used in all the best French manufactories, blowing off. his is performed by a condensing engine, as in the drawing of porter, and us access of air is prevented. This is very important where fine flavoured ines are concerned, as it is in brisk wines; because the carbonic acid which ould thus be lost, carrying away also a portion of the alcohol or strength of e wine, is thus preserved. But the leaven held in solution cannot be sepated in this manner; and for that purpose recourse is had to the process of lphuring. The most common and the simplest practice in this case, is to fill e proposed cask into which the wine is to be racked, with sulphurous gas, y burning matches in it. The wine, being then introduced, becomes turbid, nd, after the necessary time, it is found as before. Should the fermentation till be renewed or dreaded, this operation is repeated as often as it may be ecessary. If, as in the case of some of the Bourdeaux wines, the quantity f leaven in the wine is so great, that it cannot be overcome in this manner, e combustion of the sulphur within the cask is repeated at intervals during e process of filling it. But it is also a practice in that country to impregnate ith sulphurous acid a quantity of wine, and this mixed fluid, called *Muet*, s reserved for adding to those which may require it; by which means the effiacy of the operation is better ensured.

In the wine countries, it is also usual to cultivate particular grapes or wines, ough, or coloured, or astringent, or high flavoured, for the mere purpose of ixing with others; so far is this art from being so simple as is commonly imained. In many also it is a practice to import the wines of one country to mix

with those of another, and thus to suit the taste of purchasers, or obtain o ends. This practice is pursued even by the importers into Britain; and, as need not say, opens a door to endless frauds, while it may also be in Thus, in this country, as well as in Portugal, the wines of Spain, Alic nt, I celona, and so forth, are mixed with Port wines: as are the cheaper cla the south of France, and some other of the strong flavoured wines of t country. In a similar manner, the wines of Fayal and the Canaries are m factured into Madeira, as are those of Sicily; and thus, too, Sherry is l r compounded out of many of the wines of Spain and Portugal, and of Islands of the African coast.

But the most extensive operations of this nature are carried on at Bordea with the wines which we call claret, not one-thousandth part of which ar a good quality, or unmixed in some way, and the one-half of some of wh perhaps, are not French, but Spanish wine.

The French wines of which we have been speaking, w not endure to be rendered stronger by means of brandy. T property of this substance, thus mixed, is to decompose t wine in process of time; causing the extractive matter or m cilage to be deposited, as well as the colour, as is daily seen Port wines, and thus diminishing their powers of duratio At the same time, it destroys their lightness and flavour; th peculiar indefinable delicacy well known to drinkers of go wine, but quite imperceptible to British drinkers of Port. a certain sense, we may consider that it is only the bad wi which will bear this medicine; those which have no flavour their own, and whose whole merit already is their streng What sort of a compound is made of a weak wine with br dy ought to be known to those who drink what is called L bon wine. But a depraved taste has rendered it necessary our nation; and thus it is largely used, even in those wines Portugal and Spain, of which the chief fault is that of bei too strong already.

Many wines have so little flavour, naturally, that they c scarcely be considered to possess any.

Wines so highly perfumed by nature as Hermitage and Bu gundy, are rare; indeed, these are almost the only example and, after them, we may consider the finest clarets, and then th finest of the Rhine wines.

Constantia has rather a taste than a flavour; and what the o dinary sweet Spanish wines possess is rather bad than goo though, like the taste of sherry, and porter, and olives, the may become agreeable by habit.

The flavour of Madeira is nothing; but that which we kno is given by means of bitter almonds, and, we believe, of swe almonds also; and the same practice is followed for the wines Saint Lucar. The *borrachio* taste in wine is for the most pa that of the tar with which the seams of the skins are secure In sherry the flavour seems produced by the destruction of th acid, the consequence of the lime used, and possibly by sou

er action of that substance on the fruit. One of the most mmon ingredients used for flavouring wines is oak chips; and m this the wretched Lisbon wines acquire the little taste they e. Iris root is also a common ingredient; and the high fla- red wine of Johannesberg is imitated by a proportion of rose er. The iris root gives a very agreeable flavour, and is used France; and there, also, it is the custom to use raspberries other highly perfumed fruits. A very agreeable flavour is said to be produced by wormwood. The flowers of the e itself are also used for the same purpose, their smell much embling that of our mignonette.

The colouring of wine is also part of the business of the ker; because colour is, in a good measure, a matter of fashion fancy. Some grapes contain naturally very little colour, ile that of the claret vine, and many of the grapes of Spain, highly charged with the colouring principle. We already plained that the colour was contained exclusively in the husk. ese latter vines are often, therefore, selected and reserved for s particular purpose; and it is also a practice to use the dye- woods, logwood and Brazil wood, for obtaining the same d. The elder-berry, which is full of colour, is also resorted and in Portugal it used to be extensively cultivated for the rpose of dyeing Port wine. When white wines are thought o pale for the market, they are coloured browner by means of e well-known ingredient, burnt sugar; and the chips of oak so produce the same effect. By some means also iron finds way into some of the French wines, and thus, on exposure air, they become black. This unpleasant effect is not unu- al in the sweet wines from the south of France.

Briskness of wines relates almost exclusively to the wines of hampagne, and it is one that may err in excess or defect. It already apparent, that it is the produce of an unfinished fer- entation, and, therefore, a due degree of it must depend main- on the proper management of this process. It is secured by ottling at the proper season, March, and before the fermenta- on is exhausted; and, if in danger of excess, it is restrained r diminished by racking, or decanting, and sulphuring. But happens not unfrequently that it fails altogether; either from ccident in the management, or a bad season; from faults in the uit, or fermentation carried too far, or a weak wine exhausting self unexpectedly. In this case the remedy is to introduce su- ar, not only into the casks, but into the bottles.

The acidity, or the pricked taste of wines, is a fault which, erhaps, ought never to be corrected, as, in this case, the wine s generally spoiled.

For the acidity of wine from the commencement of the ace-

tous fermentation, there is no proper remedy. It may be chec if taken in time, as it would be prevented, by careful sulph ing.

To prevent it as far as possible, when commenced, a low t perature, and careful exclusion from the air, are necessary. it must be remembered that air will find access, not mer through cork, but through sealing-wax, and, indeed, through rosins also; and thus there can be no complete security; the b being that of placing the bottles on their sides, so that the fl itself becomes its own cork. The Italian practice of us oil is thus far safer; but it is balanced by its various incon niences.

The spirit may be separated from wines by careful disti tion, or, if the extractive matter be first got rid of by the ad tion of subacetate of lead and filtration, the spirit may be se rated by adding very pure and dry subcarbonate of potash, wh it will swim upon the liquor: the spirit constitutes from 12 25 per cent. of the proper wines, and from 2 to 8 per cent. the malt liquors.

Two chemists have examined the quantity of alcohol to obtained from the fermented liquors mostly in use: Newm and Brande. It appears from the comparison of their exp ments, that the wines of the present day are much stronger t they were about 80 years ago, at least in England, proba owing to the addition of brandy. Two-bottle men now act ly drink more alcohol than their six-bottle grandfathers.

### *Champagne Wines.*

The attentions required in Champagne wines are perhaps t most minute, and the most complicated, and they therefore sta most in need of being detailed. Champagne is a late countr and it frequently happens that the frosts have arrived before t grapes are ripe. A very brisk wine is not easily secured fro grapes absolutely ripe; and thus the half-ripened fruit of th district is brought into use. Yet the best of these wines, t finest class of Sillery, rarely seen in this country, is made fro the ripened grapes. And hence it is, that the best of the Cha pagne wines are those which are least brisk or violent, and th great violence is a characteristic of the inferior kinds. Wh there is violence and sweetness both, we may easily conjectu what the wine is; and in those, as might be expected, there no flavour.

The finest wine is thus produced here by a very light pre sure of the grapes; in which case only the ripest give out the juice. It is held necessary to gather them when the morni dew is off, to prevent water being added to the juice. The ne

ssure, and the least ripe grapes, are reserved for the inferior sses. When the juice is poured into the vat, it remains one ht only, the seeds being carefully separated. In all cases, , the greatest care is taken to separate damaged grapes or ten ones. If the Champagne is to be red, the fermentation is fered to proceed on the husks a little longer, for the purpose extracting the colour; and according to the length of this pro- s, we have the *oeil de perdrix*, and the pink and red wines. t this injures the flavour.

When the liquor is transferred to the cask, the discharge of st at the bung-hole is encouraged for ten or twelve days; and en the fermentation has become moderate, the bung is put vn, and a hole is made by its side. This hole is occasionally ened to give vent to the air, for a space of eight or ten days; en no more air is discharged, fresh wine is introduced, so as keep the cask constantly full to the bung-hole. This opera- n is continued when necessary, till the end of December, when wine generally becomes clear. It is then racked into a fresh k, and fined. After this it begins to ferment again, losing a rtion of its sweetness, and improving in quality. If too eet, it is not decanted and fined till the fermentation has been newed by agitation. As the fineness of this wine is one of essential qualities, and one difficult to obtain, on account its perpetual fermentation, it is racked and fined a second ne, and thus it remains till March. In March it is bottled; t still it ferments, though corked, and again it begins to depo- e. In the best wines, it thus remains from fifteen to eighteen onths in the cellar, when it is bottled over again, and is then arketable. The inferior kinds are seldom bottled twice; but expedient is used instead, to get rid of the sediment. For is purpose, the bottles are ranged in frames with their necks wnwards; and when the sediment has been collected in the ck, the cork is dexterously drawn, and again replaced, after hich the bottles are filled and completed for the market. There e varieties also in this general process, such as that of suffer- g the wine to remain in the cask for a year or more on its es; but we need not enter into these collateral details.

## *Burgundy Wines.*

There is little difference in the practice of Burgundy, except hat refers to the retention of the carbonic acid. All else is he same; but great care is taken to clear these wines of their es, as, from their extreme delicacy, they would soon lose their avour, and also become sour.

### *Claret.*

In Bordeaux also, the first stages of the process are the sa excepting in as far as a longer fermentation in the husks is to extract the colour from the red wines. But there is a di ence as to the process of sulphuring, which is largely use these, in the manner as already described. The red wine Bordeaux are racked about the end of March or the beginn of April, but the white in December; and in all these wi great care is taken in all those circumstances which rel t cleanliness, however rude the people, and the operations n appear on a superficial view.

### *Italian Wines.*

In the drier Italian wines, the must is allowed to ferment co pletely in the vat. In some vineyards, a quantity of selec and half-dried grapes is thrown into each tun when the wine finished, so as to give it sweetness, and prevent the hazar its running to the acetous stage; a rude and a bad process. the manufacture of Florence wine, the must is withdrawn f the vat as soon as the head is raised, and the wine is transfe to a cask, where it is only suffered to remain thirty-six ho when it is again decanted into a fresh cask at the end of a hours, and so on, until it is clear and marketable. Thus i completed in a short time, by little more than the proces racking.

In different countries the practices used for procuring sweet wines vary; but they will be found to depend on on other of the principles already laid down. In Italy, as in making of Florence wine, the fermentation is quelled by peated racking and shifting. Thus the other processes are pa ly or entirely saved. But it is necessary that very sweet a rich grapes should be used if this process is to be followed. ensure sweetness, on the principles formerly laid down, t grapes of Tokay are partially dried before they are used: a this is also done for the wines of Cyprus, and for some of the of France and Spain.

### *Madeira, Port, &c.*

In Madeira, the second or insensible fermentation is effect in the pipes, and, at the end of three months, the wine is racke when a certain portion of brandy is added. In both these pr tices, it would seem as if the union of the brandy with the wi was less perfect than it might be rendered by a different m nagement of this part of the process. Hence, probably,

ses, in a great measure, that the taste of brandy is so sensible many of these wines. In the best, the quantity is said to be ut a twentieth part; but, in the worst class of Port wines, eems sometimes to amount to a third or more.

### *Sherry.*

The grapes are first slightly dried, and then sprinkled with cklime. They are then wetted with brandy when introduced o the press, and a farther portion is again added to the must ore fermentation. It is highly probable that, by this prac- e, the brandy is more perfectly combined in the wine, and t fluid rendered more uniform; and hence also, probably, it ses, that the taste of brandy is not to be perceived in genu- Sherry, though often found in those baser imitations which manufactured from the tasteless wines of the Canary Islands, d of other parts of Spain. The remainder of the process for erry consists in racking repeatedly at intervals of a month or o; fresh brandy in small quantities being added at each stage this process.

### *English Grape Wine.*

We may, in conclusion, remark, that in the attempts to make ines in our own country from native fruits, the same rules are universal application, and that an attention to them would nder these domestic processes more complete than they now e, and the results more valuable. In Britain, also, it is easy make very good wine from immature grapes, by the ad- tion of sugar in the necessary proportions; and these can be rocured in almost any season, so that this might even become object of a petty domestic commerce. Nor is the manufac- ire limited to the fruit alone, since the leaves and tendrils, by fusion, admit of the same treatment, and with the same re- ults. Very tolerable wine, perfectly resembling the wines of rance, can thus be made, and at an expense of little more than he very moderate cost of the sugar.

### *English Fruit Wines.*

Wines may also be made of blackberries and other English ruits, upon the same principles. The addition of brandy de- troys the proper flavour of the wine, and it is better to omit it ntirely, (except for elder or Port wine, whose flavour is so trong, that it cannot well be injured,) and to increase the trength by augmenting the quantity of the raisins or sugar. In general, the must for wines ought to be made of raisins 6 lbs. or sugar 4 lbs. to the gallon, allowing for that contained in the fruit; and in most fruits, especially the black currant, it is ad-

vantageous to give the juice a boil previously to making it wine, as this improves the flavour greatly.

### *Malt Liquors.*

Sugar, six pounds is esteemed equal in strength to a bu of malt: the sugar employed is burnt to colour the beer inst of brown malt, and it has been proposed to employ roasted fee for this purpose.

The specific gravity of the wort intended for very weak t beer, is generally only 1·01, equal to 2 deg. Baumé; that ordinary table beer, 1·02, or 3 deg. B.; for table ale, 1·04, 6 deg. B.; for ordinary ale and beer, 1·06, or 9 deg. B.; good ale or draught porter, from 1·09, or 13 deg. B.; to 1·1, 14 deg. B.; and that for keeping liquor, 1·127, equal to 17 d B. Every 100 lbs. of this last wort is esteemed to contain lbs. of fermentable matter extracted from the grain. The s cific gravity of the wort is reduced by fermentation in an a rage, 0·075 less than it was. To ascertain the density of th worts, and its reduction by fermentation, brewers used sacc rometers of various construction.

In most of these saccharometers, the 0 showed the poin which the instrument floated in river or rain water, and 80 t at which it floated in wort that would just bear up a new egg, or a piece of yellow amber, being equal to the specific g vity 1·100. The degrees were called pounds increase per b rel, or sixpennyworths increase in the value of a bushel of m merely for mystification. The degrees are therefore reduci to the common expression of specific gravity, by adding f one-fourth the number, for the difference between 80 and 10 and then 1·000 for the specific gravity of water.

According to Blake's saccharometer, Dorchester ale when to set shows 84 deg. and when the fermentation is complete, degrees. Ringwood ale, 74 and 30; porter, 66 and 26; tab beer, 40 and 22.

One hundred gallons of wort for weak malt liquors, requi in winter two gallons of yeast, and in summer only one; f strong liquors, one gallon and a half is sufficient in winter, o in spring or autumn, and half a gallon in summer.

Capsicum and grains of paradise are used to give a pungen taste to weak beer, but to avoid detection, concentrated tinctur are mostly used; and ginger, coriander seed, and orange pe are used to flavour it: besides these, opium, cocculus Indicu nux vomica, tobacco, and extract of poppies are used to increas the intoxicating quality. Quassia is employed instead of hop as a bitter, but as this does not precipitate the mucilage, the bee soon grows muddy unless kept very cool.

Mild or new beer is made to taste like stale by adding a little of vitriol, or some alum; and, on the other hand, stale or ırish beer is made to resemble mild by neutralizing the acid oyster-shells or chalk.

When strong beer is reduced by adding small beer, publicans ually add molasses to enable it to form a head, and extract of ntian to keep the flavour.

### *Ale, or Barley Wine.*

Pale malt 14 quarters, mashed at three times with 28, 18 and barrels of water, boiled with hops 112 lbs. set with 36 lbs. yeast, cleansed with 4 lbs. of salt, produced 34 barrels or 1 llon 1 pint of ale from each gallon of malt. Burton ale yields out 8·88 of spirit in the 100, Edinburgh 6·20, Dorchester 56.

### *Draught Porter.*

Pale malt 7 quarters, amber malt 6 quarters, brown malt 3 uarters, mashed at twice with 56 and 48 barrels of water, boiled ith Kentish hops 113 lbs. set with 80 lbs. of yeast, salt 4 lbs. nd flour half a pound produced 56 barrels of porter, or 3½ gal- ns porter from each gallon of malt. A third mashing of the me grains produced 20 barrels of table beer. London porter ields little more than 4 of spirit from 100 measures. It is ell known that London porter has a peculiar flavour, the ori- in of which has occasioned much dispute. A French chemist as lately ascribed it to the smoke which it imbibes when in the oolers. Although this may not be the entire cause, it is very robable that this smoky atmosphere has some share in the ef- ect.

### *Bottling Porter.*

Pale malt 4 quarters, amber malt 3 quarters, brown malt 3 quarters, mashed at three times with 25, 12 and 12 barrels of water, boiled with ordinary Kentish hops 100 lbs. set with yeast 52 lbs. and salt 2 lbs.; produced 34 barrels, or 1 gallon and a half of porter from each gallon of malt. Brown stout yields nearly 7 of spirit from 100 measures.

### *Devonshire White Ale.*

Pale ale wort 25 gallons, hops 2 handsful, yeast 3 lbs. grouts 6 or 8 lbs. When the fermentation is at its height, bottle in strong stone half pints, well corked and wired: it effervesces when opened. The grouts here mentioned are made by infusing 6 or 8 lbs. of malt in a gallon and a half of water, covering it warm by the fire side, and stirring it often: when in full fer-

mentation it is to be boiled down to a thick paste. This singular instance of a supposed secret which has been publi upwards of a hundred and fifty years. The natives of Ki bury, in Devonshire, pretend that they alone can make w ale, and there is one family that pretends to the exclusive session of the secret of making grouts. Now the metho making grouts, and from it white ale, was published in Bauh Historia Plantarum, as being then the common English ale.

### *Table Ale.*

Very pale malt 12 quarters, mashed at three times with 32 and 32 barrels of water, boiled with hops 62 lbs. set w 114 lbs. of yeast, cleansed by the yeast head being beat in, a let to work out, produced 100 barrels or 4 gallons of ale fr each gallon of malt.

## CARBONACEOUS MATTERS,

Vary in their qualities according to the substance from wh they are prepared; that of the soft woods, as the willow or der, is best for crayons, and for making gunpowder; that of harder woods is used for fuel, or for a support for substances posed to the flame of a blow-pipe. Charcoal of animal s stances has the greatest clarifying powder. Charcoal made a low red heat, not exceeding cherry red, has a dull surface, is best for clarifying liquids, and probably for making gunpo der, or for fuel. If the heat is carried beyond this point, charcoal acquires a brilliant surface, and is considerably infer for clarifying, and probably for every other use. The great part of carbonaceous residues are used as fuel or in the manuf ture of gunpowder.

### *Carbonaceous Colours.*

Other kinds of charcoal are used as black colours.

*Beech black, blue black.* Beech wood burned in close vessels; when grou with white lead and oil, it produces a blueish gray colour.

*Frankfort black.* Made of the lees of wine, or argol, well washed and grou with water; used to make printers' ink.

*Noir d'Espagne.* Made of cork burnt in close vessels; used as a colour painting.

*Peach-stone black.* Peach stones, and the nuts of other stone fruits, as ch ries, burnt in close vessels, ground with white lead and oil, it produces th lour called old gray.

*Vine-twig black.* Vine twigs burnt in close vessels, bluish black, grou with white lead and oil, it produces a silver-white colour.

*Russian lamp black, Noir d'Allemagne.* Made by burning the chips of re nous deals, made from old fir trees, in tents, to the inside of which it ere mixed with linseed oil is apt to take fire by itself; used as a paint.

*Burnt lamp black.* Lamp black heated in a covered iron pot to get rid of i greasiness: used as a water colour, fine bone black is sold for it.

*amp black.* From distilled oils of bones burnt in lamps, with a long smoking
k: does not take fire with drying oils.
*Vood soot.* Collected from chimneys, under which wood is burnt for fuel;
tains sulphate of ammonia, it is bitter and antispasmodic.
*istre.* From wood soot, or peat, by pulverization and washing over; an ex-
ent brown water colour, superior to Indian ink for drawings, when they are
intended to be tinted with other colours.
*ory black*, called also *Cologne black, Cassel black.* From ivory shavings, or
, heated in covered iron pots; used as a dentifrice and a paint; with white
, it forms a beautiful pearl gray colour.

## *Carbonaceous Clarifiers.*

Of late years carbonaceous matter has been used as a clarify-
powder for syrup, and many other articles.

*one black, animal charcoal, charbon animal, Noir animal.* The residuum left
r the distillation of bone; reddish; used for making blacking for leather,
moulding delicate founders' work, for clarifying liquors, and for abstracting
lime used in making sugar from the syrup.
*ine bone black, Noir de Paris.* Made from turners' bone dust, burned in
ered iron skittle crucibles, and ground dry. Sold for ivory black, and when
ly levigated, for burnt lamp black.
*Prussian blue makers' black, Noir de composition.* This is the residuum from
nce the prussiate of potash has been elixiviated; that of the manufactories
ch use dried blood, clarifies far better than bone black, or than that of the
ufactories that use hoofs.
*harbon mineral.* From bituminous slate, burned in covered iron pots,
k, easily friable; used to clarify liquids, but is considerably inferior to bone
k, and does not abstract the lime from syrup.

## [BLEACHING.

Bleaching, in its broadest acceptation, is the art of removing
e colouring matter, whether naturally or artificially acquired,
m all bodies in the mineral, vegetable, or animal kingdoms.
most important applications, however, are to those fibrous
bstances, so extensively used in the fabrication of the clothing
civilized man, cotton and linen, and to these I shall devote
e principal part of this article. I shall treat first of the sub-
nces, or agents employed in art; and, secondly, of the pro-
sses and manipulations in the order in which they occur.

The materials now used in bleaching are only five in number;
z. water, lime, potash, sulphuric acid, and chloride of lime.

The quality of the water is a consideration of the first im-
rtance in the location of a bleachery. No refinement of art
s enabled bleachers to surmount the obstacles presented by
d water. Waters impregnated with the muriates, carbonates,
sulphates of lime and magnesia, or with the muriatic, carbo-

nic, or sulphuric acids, in excess, familiarly known by the t
*hard waters*, are unfit for the purposes of bleaching. T
small quantity of alkali necessary to precipitate the ear
bases and neutralize the acid, does, indeed, present no seri
objection to their use in bucking, nor is there any objectior
their use as solvents of the chloride of lime and the vitri
acid; but their bad washing properties forbids the employm
in the dash wheel where the great demand for water lies. Th
waters are readily known by the property they have of fo
ing curdy or white precipitates, on the addition of a watery,
alcoholic, solution of soap, occasioned by the union of the
neral acid with the alkali of the soap and the consequent
placement of the oil, which floats upon the surface. The p
tocarbonate of iron is sometimes found in natural waters,
is very objectionable in bleaching processes. Waters conta
ing this salt exhibit a reddish ochery scum on standing, wh
is also deposited upon the banks of pools and sluggish strea
The presence of carbonate of iron is detected by the addit
of a few drops of a tincture of nut galls, which produces a p
ple precipitate. The ferro-cyanate (formerly *prussiat*
potash will produce a beautiful blue precipitate, if the wate
previously acidulated with a few drops of sulphuric acid.
muriate and sulphate of iron are more rarely found in na
waters, but when they are present, may be detected by the s
means. They are alike injurious in bleaching.

Muddy or turbid waters are obviously unfit for the purp
of bleaching, and particularly for the last washings. They
answer for the earlier processes, provided spring or other c
water can be obtained for rinsing. This is the only specie
impurity in water which can be remedied by filtration thro
sand and gravel, which is an indispensable operation on strea
whose banks are muddy and liable to frequent and sudden
undations.

The waters of many streams, particularly those which fl
through marshy grounds, are tinged of a yellowish or green
hue, owing to their holding in solution certain vegetable u
ters. This is one of the most formidable obstacles to a g
bleach, and has not yet been surmounted by art.

From the foregoing remarks, it is obvious that the means
judging of the fitness of water for bleaching purposes are
tremely simple, and attainable by every individual without e
the humblest pretensions to science. A water that is lim
and colourless, that does not precipitate an alcoholic or wa
solution of soap, (or, in common language, that is *soft* and
*wash well*,) and that is not discoloured by the addition of
infusion of nut gall, or an acidulated solution of ferro-cya

potash, or that does not deposite an ochery matter on the ks of water courses,* may be safely relied upon as in every pect well adapted to the processes of bleaching.

Lime suitable for bleaching should be recently and thoroughburned, and colourless; in other words, lime that is white, l in other respects adapted to masonry, will answer the bleachs purpose.

Potash, the vegetable alkali, is another important agent in bleaching art. This article is never found pure in commerce; besides accidental impurities, it is always united, to a ater or less extent, with carbonic acid. Commercial potash a mixture of pure potash with the subcarbonate of potash, phate of potash, silex, minute portions of other earths, and asionally of undecomposed vegetable matters. These foign matters exist in very variable quantities in the potash of mmerce, and it becomes an important object with the bleacher find a convenient method of determining the exact amount real alkali in it, and of course the comparative value of the ferent lots offered in the market, as a guide to aid him both his purchases and in the subsequent use of it in his processes. e alkalimeter of Dr. Ure, founded on the quantity of sulphur acid required to neutralize 100 grains of potash, is a convenint instrument for this purpose. One hundred grains of pure ash will require 105 grains of concentrated oil of vitriol for fect saturation. The method of procedure is this:—provide lass tube, sealed at one end, 9 or 10 inches long, and threerths of an inch in diameter, and graduate it into 100 equal rts. It is convenient to have the graduation commence a litbelow the extremity of the open end. The exact contents this measure is not important, provided the graduation is ex. Such graduated tubes can be obtained at any of the glass uses. Into a tube of this description introduce 105 grains of ncentrated sulphuric acid of a specific gravity, 1·850, or 170° Tweedale's Hydrometer, and fill up the remaining graduated ces with water; decant the mixture into a wider lipped glass ssel, and stir with a glass rod till the union of the acid and water complete. Now, as the whole 100 measures contain a quanty of oil of vitriol equivalent to 100 grains of pure potash, it obvious that each measure of the liquor in the tube is adequate the neutralization of one grain of potash, and the number of asures required for the neutralization of a solution of 100

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* The ochery matter frequently observed to be deposited on the banks of rs from the oozing of minute springs, should not be mistaken for a depofrom the water of the stream itself, as such deposites are generally too inconsiderable to affect the general purity of the water.

grains of any commercial sample is an exact measure of the quantity of real potash contained in it, and, *vice versa*, the number of degrees remaining in the tube is the measure of the impurity contained in the sample. The point of neutralization is ascertained as usual in such cases by cautious additions of the acid, stirring the mixture on every addition, and trials of the change of colour produced on litmus and turmeric papers by the liquid. It is proper to caution the operator against a frequent source of error, pointed out by Dr. Henry in his excellent directions for the manipulations in alkalimetry, from the presence of disengaged carbonic acid, which, by acting on the litmus paper, may lead him to infer an excess of sulphuric acid. This source of error may be avoided by warming the liquor towards the end of the process, by which means the disengaged carbonic acid is expelled.

Of the oil of vitriol of commerce, one of the next most important agents in bleaching, little need be said. It is generally sufficiently pure as it comes from the manufacturer for the purpose of the bleacher. It should be colourless, and have a specific gravity of 1·850, or 170° T. If it have a specific gravity greater than that, its purity may be suspected. The chief impurities are sulphate of potash and sulphate of lead. The latter may be detected by a precipitation, on the acid being largely diluted. I am not aware that either have any injurious effect in the bleaching process. But the acidemeter is the readiest method of determining the comparative value of commercial samples, and this is no other than the alkalimeter just described, only reversing the method of procedure;—100 grains of pure potash are to be dissolved in 100 measures of water in the graduated tube, and portions of the solution added cautiously to 100 grains of the oil of vitriol to be operated on, previously diluted with four or five times its weight of water, till the acid is neutralized. The number of parts, on the graduated tube of the alkaline solution, required for this purpose, will determine the per centage of real acid contained in the sample;—if eighty parts of the one hundred degrees are required for this purpose, then is there eighty parts of real acid in every one hundred parts of the sample.

The last article essential in the bleaching process, is the chloride of lime, or bleaching powder. The introduction of this compound constituted an important era in the history of the bleaching art. What was formerly a work of several weeks is in modern bleaching, accomplished in as many days, and with a proportional diminution of labour, and great reduction in expense. The tedious exposures to sun and air, to which in the old method the goods were necessarily subjected, are

rely superseded by the use of chloride of lime. The manufacture of this article is described under the head of chloride of lime in this work. It is a dry white powder, having a slight smell of chlorine and a peculiarly strong acrid taste, not very unlike the muriate of lime. It is partially soluble in water, to which it imparts its smell and bleaching power. The undissolved portion is an hydrate of lime united with a small proportion of chlorine. The value of chloride of lime depends wholly on the amount of chlorine it contains. We meet with very variable proportions in the commercial specimens. Bleachers generally judge of the strength from the specific gravity which it imparts to the watery solution. If the powder be dry and have the odour and taste of a good article, the specific gravity is not an indifferent measure, though I have not found it uniformly correct. 5 lbs. of the best bleaching powder should impart to its solution in an ale gallon of water, a specific gravity of 1.025 or 5° T. But a more correct test of the value of this article is to be found in its power of discharging the colour from a diluted solution of indigo in sulphuric acid; for directions for using this test the reader is referred to the article, which treats of the manufacture of bleaching powder in this work. It ought to be known to the bleacher that chloride of lime loses strength by exposure to the air, and to a certain extent even when it is kept in close casks; by free exposure to the air the chlorine escapes, or is rather expelled from the lime by the joint operation of the carbonic acid and moisture of the atmosphere, and a carbonate instead of a chloride of lime remains; no more than one cask, therefore, should be allowed to be open at any one time, and that should be kept as much excluded from air and moisture as possible.

I will now proceed to describe the various processes of the art in the order in which they occur in the bleaching of cotton shirtings and sheetings.

### *The Steep.*

The goods as they come from the loom are impregnated with flour, paste, or starch, used in the process of manufacture. To free them from this foreign matter, they are thrown in loose bundles, each piece by itself, into any large vessel, or cistern, capable of containing the quantity to be operated on, which I will suppose throughout this treatise to be one ton net or 2000 lbs. The form of this vessel is a matter of no importance whatever; a common wooden cistern, such as is used for the scouring and bleaching liquors will answer every purpose, provided there is a means of warming the water in winter by steam; but if this cannot be conveniently done, a spare bucking keir may be

made use of when artificial heat is required. On the introdu
tion of every layer of cloths sufficient water should be admitt
into the steeping vessel to wet them, and, in order to sec
this object effectually, while one man is employed in put i
the goods into the cistern, another should tramp them into t
water. It is better that no more water should be used than
sufficient to cover the goods when pressed down. In this sta
the cloths should remain till a gentle fermentation is produce
which may be known by the appearance of a frothy scum upo
the water, and a sour smell from the cistern. In fact the ac
tous fermentation of the paste, and perhaps some vegetable pri
ciple of the cotton along with it, has taken place; its elemen
have assumed new combinations, and become more soluble i
water. It is probable also that the acetous acid which is forme
may at this early stage exert a solvent power on the natur
colouring matter of the cotton highly beneficial. The time r
quisite for the steep depends much on the season of the yea
or rather on the temperature to which the goods are expose
during the summer months twenty-four hours, and sometim
less, will be found sufficient for this purpose; in spring a
autumn from one to two days are necessary; and in winter art
cial heat is indispensable to despatch in business; the aceto
fermentation is very sluggish below 50° Ft.: it takes place r
dily at 60°, but does not attain its greatest activity below 8
or perhaps 90°. When artificial heat is used, care should
taken not to allow a temperature approaching to a scald, whi
is supposed to produce a change on the starch or paste, unfavo
able to the necessary fermentation when the proper temper
ture is afterwards acquired. It is scarcely necessary to rema
that the steeping process, if carried too far would endanger t
strength of the fabric. Some bleachers employ for the stee
the spent alkaline leys instead of clean water; a practice hig
ly objectionable; 1st, because it retards the fermentation; 2n
because this alkaline liquor is already loaded, perhaps saturat
with the colouring matter of the cloth, and would be mo
likely to deposite than to take up an additional quantity at t
low temperature of the steeping liquor; and, thirdly, because t
acetous acid of the fermentation must, by combining with t
alkali of the ley, have the direct effect of precipitating the c
louring matter, with which it was previously united, direct
upon the cloth. It is a singular circumstance that a practice
fraught with objections; and so opposed to the acknowledg
theory of bleaching, should have been either passed over
silence, or noticed with commendation, by all the respectab
writers, who have treated of the subject. The fermentatio
of the *steep* might be greatly expedited by the use of a ve

mall quantity of yeast made from damaged flour, which might deposited near the centre of the lot; but in this, as in the introduction of the slightest innovation upon established practices, the enlightened bleachers may calculate on encountering e prejudices of old workmen in the art. After the steep the ods are to be opened out of the band, or bundle, in which ey are usually made up, and well washed in the dash wheel. me bleachers improperly omit this washing.

### *The Liming.*

For this purpose take one bushel of good quicklime and reuce it by slaking to a dry powder; introduce it into a vessel pable of containing from 60 to 80 gallons, (a common rum uncheon answers a good purpose,) and fill it with water; agite the mixture by stirring, till it acquire the consistence of ilk;—lay into the bottom of the keir a stratum of cloth aving the bands of the folded piece previously made very ose, and while one man is employed in stirring the lime mixure, let another dash a bucket or two of it over the cloth, hich being previously wet absorbs the liquid very readily; t another layer be put in and wet down with the lime mixture, nd so on till the operation is completed. As the mixture gets w and of a thicker consistence in the lime cask, more water ust be added till the lime is all used, and the cloth all in the eir; it is better, indeed, to add a fresh bucket of water to the ixture for every bucket that is withdrawn, till towards the ery last of the lot. The manipulations in this stage of the usiness will be very easily comprehended when it is understood that the object is to diffuse a bushel of lime as equally as possible through a quantity of water sufficient to fill the keir to the grating, upon which the cloth rests, which will require from 300 to 400 ale gallons, and to spread this mixture evenly over the cloth. The agitation of the lime liquor must not be so violent as to keep suspended any lumps of lime that may remain in the powder after slaking, which must be rejected at the last; for such is the activity of this agent that it is sure to endanger the fabric where it is allowed to remain in any considerable quantity in contact with it during the boil. The cloth should be heaped a little about the vomiting pipe, so that the liquor as it falls from the pipe may subside more towards the side of the keir than it otherwise would do; much, however, depends upon the exact form of the pipe, and the violence of the ebullition; it should be the bleacher's aim to watch the boiling carefully, and adopt such little expedients from time to time as may ensure a regular and even distribution of the liquor over the surface of the cloth, and percolation through it; this

is important in all the boilings, but particularly in the limin where owing to the very sparing solubility of the lime, uneven distribution of the liquor may not only fail to pro the necessary effect upon some unexposed portions of the but, by an unequal deposition of the solid particles of lim produce such an accumulation upon other portions as to inju the texture. The fire may be kindled under the keir as soo as the first layer of cloth is introduced, and wetted with th lime liquor. The boiling should be kept up briskly, at le eight hours; ten hours' boiling will not endanger the cloth;- it is a good rule to boil in this as well as in the subsequen buckings in potash nine hours.*

As soon as the boiling is completed, the goods may be coole down by the admission of cold water, and removed from th keir. When taken from the keir the pieces are to be loose from the band; edged up, (that is, pulled over from end to en by one selvage to shake out the folds and *crimps*,) and carrie to the dash wheel. Owing to the insolubility of the lime th washing out of this boiling requires greater attention than fro any other. Some bleachers edge up and wash a second tim before the potash boil; but this is unnecessary. If the da wheel be well supplied with water, ten minutes' washing is g nerally sufficient for any purpose; the best criterion, howeve

* The whale boiler or keir, so called, is now almost universally adopted bleacheries, both in England and the United States. The bottom is compo of iron or copper with a broad horizontal flange turned up at the outer edg to which a wooden curb is attached by bolts and nuts. This curb is usua made widest at the top; the dimensions of a curb for boiling 30 cwt. of cl are usually 7 feet deep, 6 feet diameter at bottom, (that is, the grate up which the cloth rests,) and 7 feet at the top. The bottom part should hav capacity of 300 to 400 gallons. A vertical metallic tube 5 inches dia ete and open at both ends is firmly attached to the grate by a side flange, and te minates below the grate within two or three inches of the bottom of the k and above the grate within six or eight inches of the top of the curb. Th tube is generally made too small, and does not allow the liquor to pass up freely as it should do. But the particular object of this note is to point o the advantage of reversing the form of the curb and placing the largest diam ter at bottom, and the smallest at top. The object of this change in the for is to obviate a difficulty which bleachers often experience in the common kei that of the goods rising in the curb and pressing up the cover to the great lo of heat, and sometimes to the complete defeat of the boiling; for after the clot has once risen in this way, it is very difficult to get it back again till the ke is cooled down. I have tried the change proposed with great advantage, a indeed with complete success in obviating the difficulty mentioned.

With regard to the question, whether the employment of steam, or the d rect application of fire to the keir be most advantageous, I do not consider an important one, but prefer the latter; first, because a little higher temperatu may in this way be obtained than can be conveniently obtained by steam and, secondly, because the apparatus may be constructed at a less cost in th first instance, and maintained at less expense for repairs. I need scarcely ad that where steam is employed for this purpose that the keirs may be construc cd wholly of wood.

which to judge of the amount of washing required out of ther the lime or the potash boiling, is the colour of the water hich runs from the dash wheel; when this ceases to be muddy, discoloured, we may safely infer that the washing has been fficient. From the dash wheel the pieces are thrown again to bundles preparatory to the

*First Potash Boiling.*

Dissolve in an iron kettle by heat 100 lbs. of the best Amecan potash in 25 gallons of water; add to this solution while ot 25 lbs. of fresh slaked lime and stir the mixture half an our; allow it to stand till the sediment subsides, and then lade f the clear liquor into another clean iron vessel. This is a andard potash ley, each gallon of which contains four pounds potash, and should have a specific gravity of 58° Tweedale's ydrometer. Put 16¾ gallons of this solution into the boiling eir and add water till it stand 6 to 8 inches above the grate; indle a fire under the keir and lay in the cloth with the bands f the bundles quite loose; proceed in the boiling in all resects as in the boiling in lime, and keep up a brisk ebullition or 9 hours. It is usual to put the goods into the keir in the orning, and, after boiling, to allow them to remain in it over ight, and cool gradually. This will answer very well in the otash boiling; but after the boiling in lime I should hesitate to llow the cloth to lie in the keir over night without being previusly cooled down by the admission of water. In cases of great rgency it is practicable to buck twice in twenty-four hours.

From the boiling keir the cloth is again returned to the wash wheel. It is not necessary to edge up the pieces in this washng. The liquor remaining in the keir after boiling is very ark coloured, and surcharged with the colouring matter of the loth; it has lost in a great measure its causticity; if muriatic cid be added to a portion of this liquor, the colouring matter s precipitated of a dark greenish hue. By evaporating this reiduum liquor till it acquire the consistence of thick treacle, and hen exposing it to the heat of a reverberatory furnace; the vegetable matter may be burned out and dissipated, and the alkali ecovered in the form of pearlash, or the subcarbonate of potash. This was formerly practised in England, but has, I believe, now fallen into disuse. The expediency of it depends wholly on the relative value of the alkali on the one hand, and of labour and fuel on the other. Where fuel and labour are comparatively cheap, and the alkali high priced, as in Lancashire in England, this may, in some instances, be an economical practice; but where the reverse of this is true, as in the United States, the product would scarcely reward the attempt.

After washing, the cloth is allowed to drain, and is then prepared for the solution of chloride of lime.

### *Blanching Liquor.*

The solution of the chloride of lime is known to English workmen, and, I believe, very generally to our own, by the vulgar appellation of *chemic*, a term scarcely to be tolerated in a work having the least pretensions to scientific propriety. As a popular name, however, seems almost indispensable in a treatise designed for practical men, I shall designate it by the more appropriate appellation of *Blanching Liquor*. It is prepared by adding 50 lbs. of the best chloride of lime, or bleaching powder, to 50 gallons of water, stirring the liquor occasionally for ten or twelve hours, and then leaving it to settle; it is most convenient to commence this process in the early part of the day and allow the liquor to stand over night; by this means a firmer sediment is obtained, and the clear liquor is more perfectly separated from it. Add this clear solution to a sufficient quantity of water for covering the lot of cloth, (2000 lbs. as before mentioned.) The goods are to be immersed in this liquor, and particular care must be used that the bands be quite loose, and that the quantity of liquor be sufficient to cover the pieces without compressing them too hard. This solution is not so penetrating as the acid liquor, and the cisterns should have a capacity compared with the cisterns for the sours, as 4 to 3, in order that the cloth may be more fully exposed to the action of the liquor. Two thousand pounds of cloth will require for the solution of chloride of lime a capacity of about 360 cubic feet, and for the sours 270. The cloth should remain in the blanching liquor about 10 hours. It is then thrown upon a grated wooden flooring which extends about one half the cistern, and after draining an hour or two, is ready for

### *The First, or Brown Sours.*

Fill the cisterns for the reception of the goods to within three-fourths of their depths of the top with water, and add to it 40 lbs. of concentrated oil of vitriol, and stir the mixture well till the acid and water be thoroughly incorporated. The liquor will then have a specific gravity of $1\frac{1}{2}°$ or 2° on Tweedale's Hydrometer, and a degree of acidity to the taste, about equal to that of lime or lemon juice. As the souring liquor is not often entirely changed, no very exact rule can be given for replenishing the cisterns with acid; as a general rule, however, 4 lbs. of concentrated vitriol per ton of cloth for each souring will be found sufficient. The specific gravity may be some guide, but this is liable to be influenced by other matters derived from

e cloth. On the whole, the taste is the surest guide for the actical bleacher. Goods are rarely injured by too strong urs, if proper precaution be taken to prevent any parts of em from drying with the acid in them; if this precaution be glected, the destruction of the fabric is certain;—the reason obvious,—if the cloth dry with the souring liquor in it, the atery parts alone evaporate, and from being impregnated with very diluted, it becomes intimately united with a highly concntrated acid; on this account it is always better where the oods cannot be washed out of the sours, after the usual time, allow them to remain in the liquor, in preference to leaving em long exposed to the air; or, if it be necessary to withraw them from the liquor to make room for another lot, they hould be kept wet and excluded as much as possible from the tmosphere. Damage from this source is always to be suspectd where certain circumscribed spots of bleached cloths are obrved to be tender, while the general texture of the fabric is ound. Ten or twelve hours' immersion in the sours is suffient, but an hour or two, more or less, is not material. After raining, return the goods to the dash wheel.

### *Second Potash Boiling.*

The method of proceeding in this is precisely the same as in he first boiling in potash, except that only one half the quanty of potash is used. The boiling, washing, blanching, and ouring operations are repeated in the same order and manner s already described. As the goods are, however, become more ree from colouring matter, it is important that the second sourng and blanching operations should be performed in separate isterns; these cisterns are generally called by the workmen he *white chemic* and *white sours*, in contradistinction from he first liquors denominated the *brown* chemic and sours. The iquor of the brown sours should be changed after every 20 or 30 operations; but those of the other cisterns not oftener than nce a year, if proper precautions be taken to preserve them rom accidental impurities. Great care should be used that the loth be thoroughly washed out of the last sours; for, if any acid remain in the cloth when dry, it certainly will be injured. In ll the other washings it is usual to wash two pieces in each compartment of the dash wheel; but, in order to ensure a perfect washing out of the last sours, it is better to put only one piece n a compartment.

After the last washing the goods are passed through a trough of clear water, squeezed, and dried.

The order of the processes, then, as described in the foregoing remarks, are summarily these:—

1. Steep;
2. Wash;
3. Boil in one bushel of lime;
4. Wash and edge up;
5. Boil in 67 lbs. of potash;
6. Wash;
7. Immerse in a solution of 50 lbs. of chloride of lime;
8. Immerse in sours containing 40 lbs. of oil of vitriol;
9. Wash;
10. Boil in 33 lbs. potash;
11. Wash;
12. Immerse in the solution of chloride of lime;
13. Sour as before;
14. Wash;
15. Rinse and squeeze.

The whole amount of materials used is one bushel of lim 100 lbs. of potash, 50 lbs of chloride of lime, and 40 lbs. of of vitriol for 2000 lbs. of cloth.

### *Bleaching for Calico Printing.*

The bleaching for calico printing differs in nothing materia from the foregoing, except in the number and severity of the o rations. Indeed, for calicos intended for blue dipping, as well for several other styles of printing, the processes described w be found to answer every purpose. For goods intended for t madder dye, another course of work is generally advisable, a often indispensable: by the term *course*, in bleaching referen is usually had rather to the boiling than to an entire series operations of boiling, blanching, souring, and the washings; the present case I would advise another boiling in 25 lbs. of po ash, souring and washing out of each. Calico may be bleache of a beautiful whiteness, and yet contain matters that will r sist, or materially modify, the action of the madder and que citron bark dyes. Calicos intended for printing are passed twi over a red hot iron semicylinder; the object of this firing, singing as it is called, is to burn off from the side of the clot intended for printing, the nap or pile composed of the loo ends of the filaments of cotton.

Such are substantially the operations of bleaching cottons, practised for a series of years in one of the largest establis ments in this country. From personal knowledge the writ can assert with confidence that they will in all ordinary cas be found safe and effectual; how far they may be modified abridged, and yet secure the same uniform result, he is unab to decide with the same confidence. Certain it is, howeve that the number and order of the operations may be varied, a

some respects inverted, and yet afford a good bleach. Scarce- any two bleachers pursue exactly the same course of work. hroughout the state of Rhode Island, and in some other parts the country, the bleachers use no lime whatever, but confine emselves to two heavy boilings in potash; this was formerly e English practice, but the use of lime is now, I believe, near- universal in England for the first boiling. The detergent, solvent, properties of lime, in relation to all oily matters, ap- ar to be greater than those of potash, and I am inclined to ink in relation to some natural colouring principles of the oth also; in proof of this, I have often remarked that where om any cause the lime boiling had been imperfectly performed, ree, and even four subsequent boilings in potash were insuffi- ent to prepare the cloth for dyeing well in madder.

Some intelligent bleachers, with whom I have conversed on e use of lime in bleaching, entertain fears lest its corrosive alities should injure the texture of the cloth; but these appre- nsions are groundless, if the liming process be conducted in e manner already pointed out. I have never witnessed but e instance of damaged cloth from this cause, and that origi- ted in an attempt to extend the use of it. Having noticed so ten the almost indispensable importance of the lime boil to a od bleach for madder dyeing, I determined on trying the ef- ct of a second boiling in lime, as a substitute for one, or both, the usual boilings in potash. The result was, that a few eces in the top of the keir, where there was a considerable eposition of solid lime, were made very tender, while the great ass underneath remained uninjured. Fearing lest the opera- on might have been too severe to undergo another boiling, I mitted it as well as the second immersion in the blanching li- uor, and used the cloth for some styles of work not requiring very thorough bleaching. I do not regard the experiment as ecisive against the extension of the use of lime, but record it erely to show the extreme caution necessary in applying it. lad I taken the precaution to protect the upper layer of pieces ore effectually from the coarser particles of the lime, by co- ering the goods with several thicknesses of coarse gray cloth, operate as a filter, it is probable that no injury would have een done.

The practice of passing the goods immediately from the so- tion of chlorine of lime to the sours without washing inter- ediately, has often been objected to by calico printers on the pposition that the deposition of the sulphate of lime in the abric has an unfavourable effect on the madder dye; indeed a rejudice was a few years since got up in Lancashire against he use of lime in any shape in bleaching for calico printing,

but both opinions appear to have originated in partial or imp fect observation, and are now discarded by all intelligent pr ters. The omission of the washing between the immersion the solution of chloride of lime, and the sours is sometimes tended with inconvenience to the workmen, owing to the li ration of the chloride by the union of the acid with the lin This, however, is not much regarded where there is a suita ventilation of the building, when the liquor is not too stro and the goods have been allowed to drain sufficiently bef immersion in the sours;—besides, the bleaching effect is nea double what it is when the goods are washed between the t immersions; all the chlorine, which in the last case would washed away in the dash wheel, is set at liberty in the sou and most of it is taken up and becomes effective on the clot

The action of the vitriolic sours as well as of the soluti of chloride of lime on the cloth, may be much increased using them at a temperature of from 80° to 90° Ft., a the sours even at a heat of 120° or 130°, without enda gering the texture of the goods. The use of warm sours now very general, though not universal, with the English bl chers, and is partially adopted in the United States. So bleachers confine it to the last sours. The action of acid, indeed chemical action generally, is quickened by an incre of temperature, and it may be supposed that the only adv tage in the present case would be that of expediting the p cess: I am inclined, however, to ascribe to the warm liqui dilatation, or relaxation, of the fibre of the cloth, which e bles the acid to penetrate, and act upon it more thoroughly, well as more speedily than it otherwise would do. I shou decidedly recommend the adoption of warm sours in bleachi for calico printing, if not in ordinary bleaching. I do not r gard the use of a warm solution of chloride of lime so desi ble, and it is attended with some little risk of injury to t cloth; when employed, the temperature should not exceed 9 nor should the goods be allowed to remain in the liquor ov five or six hours.

Closely connected with this subject is the influence of te perature generally on the processes of bleaching; it has be often remarked by bleachers, that goods do not bleach so w in winter as in summer; and this is more frequently obser in the bleach for calico printing, where slight variations a sooner detected. An English calico printer of great expe ence, now resident in this country, informs me that he con ders the difference here fully equal to an additional boiling potash in winter, and that the same treatment will not produ a good bleach here in the winter season as in England. I a

duced to think, however, that an effect is here wholly as-
ibed to temperature, which is partly attributable to another
use;—a difference in the method of manufacture. In Eng-
nd, the weft of calicos designed for printing, is invariably
un upon *mule* spinning frames, whereas in all the factories of
assachusetts and New Hampshire, as well as in many of those
the other states, it is invariably spun upon the water, or thros-
frame; in the latter case, more twist and greater compactness
given to the yarn, and of consequence to the woven fabric,
hich, although a real excellence in the cloth for wear and du-
bility, presents greater obstacles to the penetration and action
the bleaching liquors than the cloth manufactured from mule-
un weft. It may be objected, that this explanation assigns no
ason for the difference observable between the effects of the
dinary operations of bleaching in summer, and in winter; in
ply to this objection, I can only say, that there is far less dif-
culty in determining what amount of materials and severity of
catment will produce a given effect generally, than what is
e *minimum* of materials and labour, sufficient to produce the
me results under the most favourable circumstances. It is
t improbable that the treatment already recommended is un-
cessarily severe during the heat of the summer months, and
at the experience of an English bleacher may be as inappli-
ble to the practice of the art in our climate in summer as in
inter. During a large experience in the art of calico print-
g, I have really had occasion to complain of this bleach in
e summer months, when it is scarcely possible but the opera-
ons described may have been frequently more or less imper-
ctly performed from negligence or inadvertence of the work-
en or from other unavoidable causes; yet in winter, I believe,
nperfect bleaching is with all printers in this country a source
frequent and often perplexing miscarriages.

There is another circumstance growing out of this method
spinning the weft of calicos, which has caused considera-
le embarrassment to the calico printers, and deserves to be
entioned here. It arises from an accumulation of the oil
sed in oiling the spindles about the base of the bobbin, upon
hich the yarn is spun, and caused by the carelessness of the
erson employed in oiling the spindles; the oil is suffered to
pill over the outside of the bobbin, and descending to the shoul-
er or base, accumulates there; if the yarn be raised a little
om the base of the bobbin the lower strata will be observed
be moist with oil. In the process of manufacture this oiled
arn attracts dust from the atmosphere and from whatever it
ay come in contact with, and if the cloth be narrowly in-

spected as it comes from the loom, dark transverse lines may observed in it, of from six to eight threads in width, and the lines correspond exactly with the last *picks* from the bobbi The distance of these lines asunder depends on the quanti and fineness of the yarn upon a bobbin, and the number picks in a given space; it ranges from six to eight inches different descriptions of calico; but, whatever be the distan it will always be found nearly uniform in the same descripti of cloth, or, if the spaces vary, they will be found to be twic three times, or some other simple multiple of the distan woven by a single bobbin. I am thus particular in the accou of this evil, because the real cause of it was for some time u suspected, and the source of considerable loss and perplexit in two of the largest manufacturing and calico printing establis ments in New England, and may become so to others. It an obstacle that no foreign bleacher would be prepared to e counter. Goods of this description will bleach beautifull white, yet on passing them through the weakest madder dy orange, or copper coloured stripes will appear in place of t dark ones observed in the gray state, which totally unfit t cloth for any style of printing requiring a light ground, light colour. The only remedy for this evil is great atten to the lime boiling; where this has been imperfectly performe the difficulty can scarcely be remedied by any subsequent boi ings in potash. I have sometimes boiled in potash as many five times, and given the cloth the corresponding number of i mersions in the acid and blanching solutions and washings, an yet failed to remove the evil. This shows the great superi rity of lime over potash for removing all oily matters from th cloth, and its indispensable use in bleaching for calico printing I have never encountered this difficulty except in winte months, or during the prevalence of cold weather in spring an autumn. The first cause may be, to a great extent, prevente by the manufacturer by *countersinking*, or reaming out, th upper orifice of the bobbin, and by the more careful use of oi in applying it to the spindles; but the bleacher need not rel upon a thorough correction of the evil from that source; hi processes must be sufficient to remove it in all cases, or other wise calculate on sad disappointments; for workmen will b careless, and the most scrupulous care and attention canno prevent occasional accidents. The operation of singing ap pears to fix all oily matters upon the cloth, and render thei removal more difficult for the bleacher. I have sometime thought of boiling the cloth in lime before singing, but it woul be attended with an additional expense of drying and perhap

lendering, which last operation is objectionable also on ac-
unt of its *laying* the pile which it is the object of the sing-
g process to remove.

The quality of the stock, of which the calico is manufactured,
another circumstance calculated to modify very much the ef-
cts of the bleaching agents upon it. Some cottons are natu-
lly of the colour of *nankins*, and others nearly white, (at
ast they have that appearance in the unwrought state.) I am
able to say whether the different species require a severity of
eatment exactly corresponding with the differenee in the depth
colour. It is so said by some writers, and the opinion is,
obably, nearly correct.* The foregoing directions for bleach-
g, however, have reference only to calicos fabricated from
orth American, and for the most part from New Orleans and
land, cottons, which are very white eompared with many
ecies grown in other parts of the world.

Coarse cloths, and other things equal, are bleached with much
eater facility than fine: fine yarns have necessarily more twist
them than eoarse, and therefore present greater mechanical
stacles to the penetration of the bleaching liquors; in like
anner the closeness and firmness of the texture of the woven
bric has great influence in resisting the action of the bleaehing
ents. Few bleachers, I apprehend, are fully aware of the va-
tions in the amount of materials and labour which these dif-
rences in the fabric will admit of. The foregoing remarks
ay be considered as applicable to eloth manufactured from yarn
forty skeins to the pound, and having about eighty threads
the inch, warp and weft; an equal weight of No. 14 shirt-
gs may be bleached (even for madder dyeing) for from one-
lf to two-thirds the amount of materials and labour.

I subjoin the following as the order of the processes, and the
nount of potash used at a large establishment for bleaehing and
lico printing in Massaehusetts, for which I am indebted to the
bliteness of the superintendent of the works. The reader will
bserve it is somewhat more severe than that recommended in
he foregoing pages. The quantity of cloth operated on is
000 lbs.

*Bleach for Madder Dyeing on No.* 40 *Calico.*

1. Steep;
2. Wash;
3. Boil in lime;
4. Wash twice, but not edge the pieces;

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* Berthollet says that, in general, yarns of a yellow colour bleach with more
ifficulty than those of a gray hue, bordering on brown.

5. Boil in 74 lbs. of potash;
6. Wash;
7. Boil in 40 lbs. of potash;
8. Wash;
9. Immerse in a warm solution of chloride of lime;
10. Sour (warm;)
11. Wash;
12. Boil in 20 lbs. of potash;
13. Wash;
14. Immerse in a warm solution of chloride of lime;
15. Sour as before;
16. Wash;
17. Boil in 20 lbs. of potash;
18. Wash;
19. Sour;
20. Wash;
21. Rinse and squeeze.

*Bleach for Blue Dipping, (Blue and White,) No. 30 Clot*

1. Steep;
2. Wash, (in cases of urgency this washing is omitted;)
3. Boil in lime;
4. Wash;
5. Boil in 40 lbs. of potash;
6. Wash;
7. Immerse in chloride of lime (warm;)
8. Sour (warm;)
9. Boil in 27 lbs. of potash;
10. Wash;
11. Rinse and squeeze.

The same as the last for white goods, only with an addition souring and washing after the second boiling in potash.

### *Bleaching of Linen.*

The bleaching of linen differs from that of cotton in nothir but the number and severity of the operations. The colourir matter of linen is less soluble, and probably more abundan than that of cotton. About double the amount of materials an number of operations of boiling, washing, souring, &c., are r quired to produce a good white.

### *Theory of Bleaching.*

The theory of bleaching is not well understood. The exper ments of Mr. Kirwan, published in the Irish Transactions fc 1789, throw the most light of any that have appeared on the n

re of the colouring matter of cotton and linen. He precipitated, means of muriatic acid, the colouring matter from an alka- e ley, in which linen yarn had been digested, and found it to ssess the following properties:—

When suffered to dry for some time on a filter, it assumed a rk green colour, and felt somewhat clammy, like moist clay. A small portion of it was perfectly insoluble in sixty times weight of boiling water.

The remainder being dried in a sand heat, assumed a shining ack colour; became more brittle, but internally remained of a eenish yellow, and weighed one ounce and a half. By treat- g eight quarts more of the saturated ley in the same manner, obtained a farther quantity of the greenish deposite, on which made the following experiments:—

"1. Having digested a portion of it in rectified spirits of ine, it communicated to it a reddish hue, and was, in a great easure, dissolved; but by the affusion of distilled water the lution became milky, and a white deposite was gradually rmed: the black matter dissolved in the same manner.

"2. Neither the green nor the black matter was soluble in l of turpentine, or linseed oil, by a long continued digestion.

"3. The black matter being placed on a red hot iron burned th a yellow flame, and black smoke, leaving a coaly resi- ium.

"4. The green matter being put into the vitriolic, marine, d nitrous acids, communicated a brownish tinge to the two rmer, and a greenish to the latter, but did not seem at all di- inished.

"Hence," says Mr. Kirwan, "it appears that the matter ex- acted by alkalies from linen yarn, is a peculiar sort of resin, fferent from pure resins only by its insolubility in essential ls, and in this respect resembling lacs." He then proceeded examine the powers of the different alkalies on this substance: ght grains of it being digested in a solution of crystallized mi- eral alkali, saturated at a temperature of 62°, instantly com- unicated to the solution a dark brown colour; two measures ach of which would contain eleven pennyweights of water) d not entirely dissolve the substance. Two measures of the ild vegetable alkali dissolved the whole.

"One measure of caustic mineral alkali, whose specific gra- ity was 1·053, dissolved nearly the whole, leaving only a white siduum.

"One measure of caustic vegetable alkali, whose specific gra- ity was 1·039 dissolved the whole.

"One measure of liver of sulphur, (sulphuret of lime,) whose pecific gravity was 1·170, dissolved the whole.

"One measure of caustic volatile alkali dissolved also a p tion of this matter."

So far the theory of the art is very simple and obvious; colouring matter of the cloth consists in a great degree of a sinous substance, soluble only in alcohol, the alkalies, sulphu of lime,* and we may add, from more recent experience, in li water, and perhaps to a degree in caustic magnesia; and dur this solution the alkali loses its caustic property, and becon comparatively mild even to the taste. But the alkaline so tions will not remove all the colouring matter from the clo after a few boilings the solvent power of the alkali, even of fre portions, seems to cease, and no more colour is extracted till t cotton or linen, as the case may be, is exposed to the action air and sun, or to a solution of chlorine, or some of its co pounds with the alkalies or earths; after which, although t effect of these last agents is to whiten the fibres, the alkali rec vers its solvent power over this principle in the cloth, and wh digested upon it loses again its caustic properties, and what more remarkable acquires a brown colour. The most am experience has demonstrated the necessity of employing th agents *alternately* in order to a perfect bleach; neither will fect the object singly, nor both consecutively, whichever n be applied first. It is probable that the peculiar effects of and air, and chlorine, and its compounds, upon the colour matter of cloth are referrible to the same principle, and that t principle is oxygen; it is certain that chlorine is thereby c verted into muriatic acid, and its compounds into muriates; b whether the oxygen unites directly with the colouring mat as a whole, or forming a peculiar compound, or, combining wi the hydrogen of the vegetable principle, reduces it to a solub state, cannot be determined till we know more of the nature a constitution of the vegetable principle, or principles, which is the object of the bleaching art to extract.

We are equally in the dark as to the agency of the acids bleaching. The earlier bleachers of the modern school direc in the bleaching of cotton fabrics, the use of the vitriolic sou only as a finishing process, to dissolve out any iron which mig be deposited by the previous buckings in potash; such is t opinion of Berthollet and Hume; for linen they do, indeed, r commend three or four applications. That the solution of ar oxide of iron deposited on the cloth is one effect of the sour

* This article was introduced into the bleaching art in Ireland some years ag at the suggestion, I believe, originally of Mr. Kirwan. It is a very powerf solvent of the colouring matter of linen, but was found to be an unsafe app cation on a large scale, and has now fallen into disuse.

cannot be doubted: in proof of this, Berthollet informs us, (and very scientific bleacher is, perhaps, aware of the fact from experiment, "that the prussiate of potash occasions, after some time, in the sour a blue precipitate; but," the same writer continues, "is the action of the acid confined to the above use? if it be, why repeat this operation four times, and apply a ley between each of them, while for cotton equally exposed to be stained by the ferruginous deposite a single sour is sufficient?" The suspicion implied in this interrogatory, that the most important agency of the acid in the bleaching art was not yet understood, would have been still stronger had the writer known at that period the decided advantage derivable from earlier and repeated use of this agent in the bleaching even of cotton. The acid of the bleaching sours does not appear to suffer decomposition. It is not improbable but its agency may be exerted in changing the relations of the elements of water to the other ingredients of the colouring matter, somewhat analogous to the action of diluted sulphuric acid on starch and some other organic compounds, and thereby rendering it more soluble in the other liquids employed.

The best arrangements for drying cloths are noticed under the head of "drying rooms" in this work.

To cover a tendency in bleached cloths to assume a slight yellowish tint in drying, it is usual to tinge the last rinsing water with a minute quantity of some blue material, and this process is called the blueing. The sulphate of indigo is sometimes used for this purpose, though minutely ground indigo diffused in the water is generally preferred. But the most delicate shade is imparted to the cloth by the use of finely ground smalt, diffused through the water in the usual manner of applying the solid indigo.

The remaining operations of calendering, folding, pressing, &c., to fit the goods for market, are strictly mechanical, and do not come within the province of this work.]

## [CALICO PRINTING

Is the art of topical dyeing. In treating of it I shall endeavour to adopt such an arrangement as shall appear most conducive to the instruction of a person tolerably well versed in the principles of chemical science; having access to the ordinary mechanical arrangements of a calico printery, but little or no acquaintance with the peculiar processes of the art.

## *Madder Dyeing.*

Madder belongs to that class of drugs, the colouring ma of which cannot be permanently fixed upon cloth without intervention of some metallic or earthy substance, capable forming a ternary compound with colouring matter and cloth; such colouring principles have been denominated by Bancroft *adjective* colours, in contradistinction from those lours which may be made to unite permanently with the fa without the intervention of a third substance, and which calls substantive colours. The metallic or earthy bases ( ployed in *fixing* vegetable colours, are called *mordants.*

There are but two mordants, or rather but two classes of m dants now employed in fixing the madder dye, the salts of a mine and iron, which, either singly or combined, are capa of producing a great variety of colours.

### *Of the Aceto-Sulphate of Alumine, or Red Liquor of t Calico Printers.*

Pure alumine has a strong attraction for the colouring m ter of madder, (as well as for that of various other dye-stu but being insoluble in water, it is necessary to employ i union with an acid in the form of a neutral, or rather a su acid, salt dissolved in water; the cloth is first either soake printed in parts with this solution, and afterwards dyed in madder. In ordinary dyeing, where the cloth is not necessa dried between the application of the mordant and the dy process, (that is, in what the dyers call *fancy dyeing* on ( ton,) common alum (the super-sulphate of alumine and pot is employed; but in topical dyeing, where only parts of the bric are impressed with the mordant, and where the cloth is avoidably dried and exposed to a warm temperature betw these two operations, the pure sulphate (as well as the mu ate and nitrate) of this earth is inadmissible, on account of tendency to crystallize before the cloth becomes thoroughly pregnated with its base. The acetate of alumine is not a cr tallizable salt; and is, therefore, generally employed in cal printing.

As native alumine is not soluble in the acetic acid by dir means, the red mordant is obtained by double decompositi for this purpose

Take 100 gallons of water;
300 lbs. of alum;
168 lbs. of sugar of lead;
30 oz. of carbonate of lime (whiting) in fine powd

Dissolve the alum in the water by heat; then add the whit

degrees, and, last of all, the sugar of lead, and stir a few nutes; the decomposition is almost instantaneous; the sulphu- acid of the alum combines with the oxide of lead of the ace- te of lead, forming an insoluble sulphate, and the acetic acid the acetate of lead unites with the alumine of the alum, form- g an acetate of alumine, which remains in solution. The whi- g is added to neutralize a part of the excess of acid of the um. As soon as the sulphates of lead and lime have subsided, e clear liquor may be decanted; it will have a specific gravi- at 60° Fahr. of 1.090 or 18° on Tweedale's Hydrometer. fore the addition of the whiting its specific gravity is 1.095 19° T., (that is, at 60° Fahr.,) owing to the presence of sul- uric acid. Although three ounces (to the gallon) of carbo- te of lime have been added, there is still a considerable excess acid; there is as much, in fact, as would combine with four d a half ounces more to the gallon; for each pound of alum ill combine with two and a half ounces of carbonate of lime thout parting with an atom of its alumine: it is advisable, wever, to retain this excess of acid, otherwise the colours will t be so bright, and the liquor will become stiff when boiling t; this last circumstance is owing to a singular property, first inted out by Gay Lussac, that the solution of acetate of alu- ine possesses the power of precipitating a part of its base when t, and redissolving it again when cold. The excess of acid events this effect. There is also in this mordant a very con- derable excess of alum; one pound of sugar of lead will de- mpose only three-fourths of a pound of alum, and yet we ve but $2\frac{68}{100}$ lbs. of sugar of lead to 3 lbs. of alum. This mor- nt is, in fact, an aceto-sulphate of alumine. An excess of um is, however, found useful, for the same reason that an ex- ss of acid is. It has always been objected to by theoretical emists, and as invariably insisted upon by the calico printers; ere is a considerable diversity of opinion as to the exact propor- ons of sugar of lead and alum, but all agree in using an excess of e latter. The smallest proportion of sugar of lead to the alum, commended by good printers,* is 1 to 2, and the largest pro- ortion $2\frac{1}{2}$ to 3; within this range we meet with every possible roportion. The proportions given above are such as I have und to answer on a most extensive scale, but will not under- ke to say that they are the best that could be. It has been bjected to so large an excess of alum; that it imparts to e liquor a bad thickening property with flour, that of being pt to separate from the liquor. This difficulty, however, I

* Berthollet directs 1 to 3 in his work on dyeing, but the best English cali- o printers rarely use these proportions.

have ascertained to be more dependent upon the excess of a of the alum than to the salt itself, and have accordingly us and directed rather a larger quantity of carbonate of lime thai usual. It is said that an ounce or two of common salt, add to each gallon of the liquor, will obviate this objection; bu have never had occasion to use it.

A cheaper method of obtaining the red mordant is to subs tute the acetate of lime for the sugar of lead in the double c composition with alum.

### *The Acetate, or Pyrolignate of Lime*

Is prepared by saturating the impure acetic, or pyroligneo acid with quick lime. One hundred gallons of the impure p roligneous acid of a specific gravity of 7° T. will require f perfect neutralization from 70 to 75 lbs. of lime. Slake 60 lb of lime with a portion of the acid, in the usual way of slakii lime with water,* and afterwards add the remainder of th acid, and stir frequently for two days. If the acid is not a neutralized, which may be ascertained by the taste with suf cient precision, continue to add lime in small quantities till it so. If the lime is new and quick, a scum of charred tar wi rise upon the surface of the liquor on standing a day or tw from a half to one inch in thickness; about 75 gallons of cle liquor may be obtained from the above quantities of lime a acid, which should be carefully decanted from the muddy dep site of lime and tar at the bottom. The solution when finish should have a specific gravity of 16 or 17° T., if it mark high than 16°, it may be reduced to 16° by dilution with water. the lime liquor be used of a specific gravity of 19 or 20° T in the decomposition of alum, the sulphate of lime will not pre cipitate well, and it is almost impossible to obtain a clear solu tion without large dilution with water, which of course will re duce the standard mordant too low. To prepare the aceto-su phate of alumine from this liquor,

Take 100 gallons solution of pyrolignate of lime at 16° T.;
300 lbs. of alum.

Dissolve the alum by heat in the pyrolignate of lime; skin the top, and let the sulphate of lime subside; when cold decan the clear liquor. It will have a specific gravity of 22° T. a 60° Fahr. On standing a few days a thick scum of tar will rise

* It might be objected to slaking the lime with the red liquor, on the groun that the heat generated will evaporate, if it do not decompose a portion of th acetic acid, (which is not improbable;) but a clearer liquor (more free fron tar) is obtained by this process than if lime were used in the state of a hy drate.

hich must be skimmed off, and the specific gravity will then somewhat lower,—at about 21° T.

The precipitated sulphate should, in this case, as well as in e decomposition of the acetate of lead, be carefully washed by ding to it a quantity of water equal to one-third or one-half the antity employed in the first instance; a weak solution of the ordant may in this way be obtained, which will always come use for the lighter shades of colour, and is a clear saving of hat is not unfrequently thrown away by negligent colour ixers.

In preparing the aceto-sulphate of alumine, by either of the regoing methods, care should be taken that the material be as e as possible from iron. The white crystallized sugar of lead ould be preferred. There are considerable differences in the ality of alum met with in our market. The comparative rity, in this respect, of the different samples may be ascerined with tolerable accuracy by the depth of the colour of preipitates produced by the solution of the ferro-prussiate of iron, tincture of nut galls, on solutions of the same strength. A fficient test of the freedom of lime from iron is its whiteness. he pyroligneous acid, from the universal practice of distilling from iron vessels, always contains more or less iron, and nce the reds and yellows dyed on the mordant, prepared from are never so bright as from that prepared from the best sugar lead. We occasionally meet with an impure brown sugar of ad in the market, prepared from litharge and the pyroligneous id, which is not at all superior to the pyrolignate of lime for is purpose, and which yet bears a price nearly equal to that the purest article. Various attempts have been made to proure a purer acetic acid for this purpose from the fermentation malt, from diluted alcohol, &c.; but they have all been found be either more expensive than the acetate of lead or lime, or ttended with some other disadvantage, which has prevented eir successful introduction into general use.

The *red liquor* prepared from sugar of lead affords a brighter olour both with madder and quercitron bark, than that from e acetate of lime, and is therefore generally employed where ery bright and delicate colours are required; particularly for inks, pale reds, and yellows. For deep full reds the liquor om the acetate of lime is more generally used; and for all hose colours in which the red mordant is mixed with iron liuor, it is equally good as that from the sugar of lead.

The red mordant from pyrolignate of lime will afford a much righter red, if the cloth be dyed up immediately after it is printd, before the acetate of iron, with which this mordant is conaminated, becomes decomposed and fixed upon the cloth.

As there are no distinctive appellations for this mordant, w prepared in these two ways, I shall, in the remaining formul distinguish them, to save circumlocution, by the terms *old* and *new* red; that prepared from sugar of lead and alum hav been longest in use, I shall denominate *old* red, and th fr pyrolignate of lime and alum, *new* red, liquor, or mord t.

The *old* red mordant at 18° T., and the *new* red mord at 21°, may be considered as standard liquors, capable of affo ing the deepest red with madder, and yellow with the que citron bark. For the lighter shades of colour they are dilut with one, two, three, four, or five parts of water, according the shade required and denominated No. 1, 2, 3, 4, or 5 re according to the number of parts of water added. It is se dom that a lighter shade of red is wanted than will be produce by five waters to one of the standard liquor.

### *Sightening for the Aluminous Mordant.*

To enable the printer to see the progress of his work, a to judge of the impression he is making, it is usual to tinge t mordant with some fugitive colouring matter before it is thi ened. It is a convenience, though not absolutely necessary, have the mordant sightened (as the printers term is,) of t same colour as that of which the calico is intended to be dye For red liquor,

Take one gallon of the aluminous mordant (old red is pr ferable,) and digest for twelve hours on one pound of groun peach wood at a temperature not exceeding 100 Ft., strain an make up the loss of liquor by evaporation with water. Half pint of this decoction will sighten one gallon of colour for m chine printing, and two gallons, if applied by the block. Wher a diluted mordant is required, a decoction of peach wood i water may be used, and constitute a part of the water used fo dilution.

### *Thickening for the Aluminous Mordant.*

The object of thickening is to prevent the colours from spreading upon the cloth. For this purpose gum Senegal, flour, starch, and British gum, (calcined starch,) are generally employed. Gum imparts to the mordant the best working properties, but its expense forbids its use for common work, according to the opinion of most printers; where, however, it can be obtained of a good quality for 12½ cents *per lb.*, it is as cheap as flour at $7 per barrel, and particularly for block work, it expends better; the colour it affords is brighter, and there is much less waste than with flour paste; if two pieces of cloth

e examined after they are dyed, the one of which was blocked
the red mordant thickened with gum, and the other with the
me mordant thickened with flour, the piece printed in gum
lour will be found to show a brighter colour on the face than
at thickened with flour, and a poorer colour at the back. The
eason of this difference seems to be that the paste separates
ore readily from the dissolved mordant, and suffers the latter
transude through the cloth, and pass to the back side, leav-
g the paste upon the front surface; whereas the gum holds
e mordant with greater tenacity, does not suffer it to separate
easily from it, and accordingly deposites a larger portion
pon the face of the goods.

*Standard Gum Red.*

Take 10 gallons of Red Liquor (old or new;)
55 lbs. Gum Senegal.

Add the gum to the liquor, and let it stand from 12 to 24 ours, without agitation, then stir till dissolved, and strain hrough a cloth. The solution will have a specific gravity, if he gum be good, of 35 or 36° T. Stir in more red liquor till he specific gravity is 34° T. This mordant is rarely worked o stiff as this, but the printer is allowed to thin it by the ad- ition of more liquor till it have the required consistence. As strong solution of gum will not undergo spontaneous decom- osition, this thickened mordant may be kept for months and erhaps years without injury.

If lighter shades are required, nothing is necessary but to educe the strength of the "standard gum red" by the addition f one or more parts, as the case may be, of a solution of gum Senegal in water, of the same specific gravity as the gum red.

*Standard Paste Red.*

Take 1 gallon of standard Red Liquor;
2 lbs. Flour (sifted.)

Add the red liquor by degrees to the flour, and beat it up nto a perfect paste; then turn the mixture into a copper boiler, and boil 15 or 20 minutes, stirring all the while to prevent the paste from caking to the bottom and sides of the boiler. Two lbs. of flour is the average quantity required for paste intended to be worked by the engraved cylinder; but some patterns re- quire more and some less. The average quantity for paste to be worked by the block is about 1½ lbs. In either case, if the paste be too stiff, it may be thinned by stirring in a small quan- tity of the unthickened liquor, but the paste is scarcely so good

as when the right consistence is obtained in the first instan This paste will not keep well, and in warm weather must *worked* the day it is prepared, or, at farthest, the day after.

*Another (for the roller.)*

Take 1 gallon of standard red liquor;
28 oz. of flour;
4 oz. British gum.

Beat up the flour and gum in separate portions of the liquo then mix, and proceed as in the last case. The British gu is thought by some to improve the working properties of th paste.

Some calico printers make use of equal parts of starch an flour for thickening this mordant; but starch is in no respec better than flour, and treble or quadruple the cost.

The mordant for yellows is the same as for reds, with the ex ception that it is usual and convenient to sighten the liquo with a decoction of quercitron bark instead of peach wood.

*Protacetate of Iron, or Iron Liquor.*

This important mordant may be prepared either by the d rect union of its component parts, or by double decomposition The first method is now generally practised, and consists in d gesting the crude acetic, or pyroligneous acid, of a specific gravi ty of 7° T., upon an excess of clean malleable iron, in a state o minute division, till the liquor has acquired a specific gravit of 18° T., at the temperature of 60° Ft., which point must b ascertained by cooling a small quantity dipped from the boile from time to time, and testing it by the hydrometer. A large cas iron boiler should be employed, and the liquor kept at a tempera ture not to exceed at any time 150° Ft. If clean wrought iron turnings* be used, and in considerable excess, the process may be completed in from 5 to 7 days. Considerable tar rises du ring the solution, which should be skimmed off: a still heavier scum will continue to rise after the liquor is cold, and, indeed, for days and months afterwards, a part of which it is better to allow to remain undisturbed, till the liquor is wanted for use. and more particularly if it is exposed to the action of the air in an open cistern.

Some printers prepare this liquor without heat; but the pro cess described is preferable; when the solution is effected with-

* Cast iron and steel, even in the minutest state of division, are nearly insolu ble in acetic acid.

t heat, the tar attaches to the surface of the iron, impedes e action of the acid, and renders the process extremely te- ous; there is also in the latter case more risk of peroxidizing e iron, particularly if the liquor be much exposed to the air pumping, or pouring it backwards and forwards from one ssel to another, as erroneously recommended by most writers this subject, and still practised by many calico printers. fter repeating this operation two or three times, the iron be- mes so coated with tar, notwithstanding the use of heat, as make it necessary to remove it, and supply its place with a sh quantity. It is generally recommended to burn off the from the iron by exposing it to the flame of a reverberatory rnace, and use it a second time; but I have not found the actice to answer a good purpose; the tar may, indeed, be ssipated in this way; but the surface of the iron, and in fact e whole of it, if turnings be used, is converted into the black utoxide, which is perfectly insoluble in acetic acid. It is fficult to obtain wrought iron turnings free from rust; the ater used to wet the tool in turning, unless carefully dried off ter they are formed, (and which the machinest of course will t attend to,) is sufficient to convert a part of the iron into the roxide in a very short time, and which forms with the ace- acid a peracetate; a mordant wholly unfit for many, and in- rior for any, of the uses of the calico printer. This rust ay be readily removed by washing the iron turnings, pre- ous to use, with a very dilute solution of sulphuric acid in ater, and afterwards rinsing them in clean water.

From 100 gallons of pyroligneous acid, with the requisite quan- ty of iron, from 60 to 70 gallons of iron liquor at 18° T. may be tained. This solution, reduced to 12° T., is sufficiently strong produce a deep black with madder, and may therefore be re- rded as the standard iron liquor, or black mordant.

This mordant may also be obtained by the double decompo- tion of the acetate of lead, or lime, and the proto-sulphate of on; for this purpose,

Take 1 gallon of water,
4 lbs. of persulphate of iron, &c.,
2 lbs. of acetate of lead.

Dissolve the sulphate of iron in the water, and then add the gar of lead; stir the mixture till the decomposition is com- lete, which is almost instantaneous, if the solution of copperas e hot when the lead is added; when the sulphate of lead has bsided, decant the clear liquor. There remains a considera- le excess of undecomposed copperas in this solution.

The acetate of lead is, however, never used for this mordant,

unless as an extemporaneous preparation, where the acetat lime is not at hand. To prepare the iron mordant from latter,

Take 75 gallons solution of pyrolignate of lime at 16° T
400 lbs. of proto-sulphate of iron (green copperas;)
100 gallons of water.

Dissolve the copperas in the water by heat; then add the p rolignate of lime, and stir well together; when the precipit has subsided, decant the clear liquor. This liquor at 60° Fa will have a specific gravity of 22° T., and reduced to 12° by the addition of water, is supposed to have about the sa strength as that prepared by the direct solution of iron in t pyroligneous acid of the same hydrometrical strength, and whi I have assumed as a standard.

The acetate of iron is preferred to the salts formed by t mineral acids with this metal, for the same reasons that have ready been assigned for a preference of the acetate to the s phate, muriate, and nitrate of alumine.

All the green salts of iron (that is, all those which have t protoxide for their base) have the property of attracting oxy from the air, precipitating a portion of their base, passing to highest state of oxigenation, and forming super-acid salts, w the peroxide for their base. Owing to this circumstance, iron liquor, which is a protacetate, should be excluded from t air as much as possible; but it is difficult to exclude it altogeth and where this mordant is kept on hand for a considerable leng of time, as it must often be, I would recommend adding to from time to time, small quantities of clean iron turnings, whi will detach and combine with the oxygen of the peracetate, r storing it again to the protacetate, and unite with and neutrali the free acid. To prevent too great an accumulation of sedime in the casks or cistern, by these additions of iron, the turnin may be suspended in the liquor by a coarse netting.

No sightening is necessary for the iron mordant, prepar with pyroligneous, when used of the standard strength, as t solution is sufficiently coloured without it; for the diluted liqu a decoction of logwood (one pound to the gallon) chips must used. The logwood is preferable in the form of chips, rath than in a ground state, on account of the difficulty in the lat case of obtaining a clear decoction.

### *Standard Gum Black.*

Take 10 gallons of iron liquor at 18° T.;
5 gallons of water;
100 lbs. of gum Senegal.

Dissolve the gum in the water by heat, and when dissolved ur it into the iron liquor, and stir briskly till the mixture is rfect. The colour when cold will mark 36½ or 37° T. Di- e with iron liquor till the mixture have a specific gravity of 3° T. This method is preferable to dissolving the gum direct- in the iron liquor at 12° T.

The standard iron liquor, diluted with from one to twelve ters, forms various shades of purple, which are thickened h gum, or flour, as the case may require. The process of ckening iron liquor with flour is the same as with the alumi- us mordant already described.*

*Mordant for No. 1 Chocolate.*

Take equal parts of iron liquor at 12° T., and new red liquor 22° T.; mix and thicken with flour. The iron liquor should sightened with logwood.

*Mordant for No. 2 Chocolate.*

Take 1 part of iron liquor at 12° T.;
2 parts of new red liquor at 22° T.

Mix and thicken as before. The foregoing and intermediate ades are best suited for cylinder patterns; for the block three four parts of red liquor to one of iron are of frequent use.

*Mordant for a Purple.*

Take 1 part of iron liquor at 12° T.;
1 part of water, sightened with logwood;
One-tenth part of new red liquor at 22° T.

Mix, thicken, &c. This mordant affords a beautiful shade ith madder. The common printers' No. 1 purple is the same the above, leaving out the red liquor; but the colour is much nproved by this addition; this is intended for the machine; for e block lighter shades, but the same relative proportions may e used.

*Mordant for a Dark Mulberry.*

Take 3 parts of iron liquor at 12° T.;
1½ part of new red at 22° T.;
1½ part of water sightened with a decoction of logwood.

Thus by varying the strength as well as the relative propor- ons of the two mordants, an almost infinite variety of shades ay be produced.

* It may be well for the colour mixer to know, that boiling over 15 or 20 mi- utes has a tendency to render the paste too *gluey*.

### *Mordant for Blue Lavender (for the block.)*

Take 10 parts of iron liquor at 12° T.;
1 part of new red at 22° T.;

Mix for a standard; then of this standard take 1 part, and 10, or 12 parts of gum water, according to the shade require

### *Mordant for Red Lavender (for the block.)*

Take 3 parts of new red at 22° T.;
1 part of iron liquor at 12° T.

Mix for a standard; then take of this standard 1 part, and 5, or 6 parts of gum water, according to the shades wanted.

## *Machine Printing.*

Machine printing differs from copper plate engraving in n thing, essentially, except the mechanical arrangements necessa for operating with a cylindrical instead of a flat surface.

Fig. 237 exhibits a vertical section of a machine printing and stoving ro in such a direction as to show an end view of the printing machine and r for the distribution of the cloth and machine blanket in the stoving room. the stoving room; *B*, the machine room, and *C*, the dividing wall betw them; *a*, the printing machine. The figure intended to be printed on the lico is engraved upon a hollow copper cylinder, *t*, which is fixed during the o ration of printing upon a horizontal iron mandril, or arbor, which revolves w it. Immediately underneath the copper roller or cylinder, and in contact w it is a wooden roller, *t t*, called the furnishing roller, covered with woollen clo which revolves with the copper roller; this furnishing roller revolves in a b *v*, which contains the colour or mordanted paste to be applied to the cali and is imbedded in it to the dotted line; the view of the colour box sho strictly be concealed by the lever *e*, but for illustration is represented as if se through it. During the revolutions of the copper roller, and the furnish roller, the under surface of the former is constantly besmeared with the col or paste; the plane or unengraved surface of the copper roller is afterwar freed of the colour by a thin straight edged plate of steel, *w w*, called the do tor, which rests obliquely upon the copper roller, and scrapes the superfluo colour back into the colour box, leaving the engraved portions of the cylind filled to a level with the unengraved parts. The white calico intended f printing, is first rolled smoothly upon a small wooden hollow cylinder, whi slips upon an iron centre or shaft, and which has small friction levers resti upon its gudgeons, and weighted to prevent the calico from unwinding too e sily, and to give a tension and smoothness to the cloth as it enters the machi *q* shows the roll of calico, and *p p* the lever and weight of one end. Fro this roller the cloth is conveyed to the machine over the rollers *q q q q*, in ord to allow room for the workman to come at the back of the machine; the clot then passes through the machine between the engraved copper roller and t iron roller *c*, and thence to the stoving room in the direction of the dotted li at *h*. As soon as the end of the piece is passed through the machine, the ir roller, *c*, is pressed firmly down upon the copper roller by the screws at *d* op rating upon the steps of its gudgeons; in many of the old machines these screw constitute the only compressing force, but more recently this force is really a plied by weighted double levers which affords a constantly operating pressur and at the same time one that will yield to slight inequalities in the thickne of the cloth or blankets interposed between the two rollers; *e f* are the do

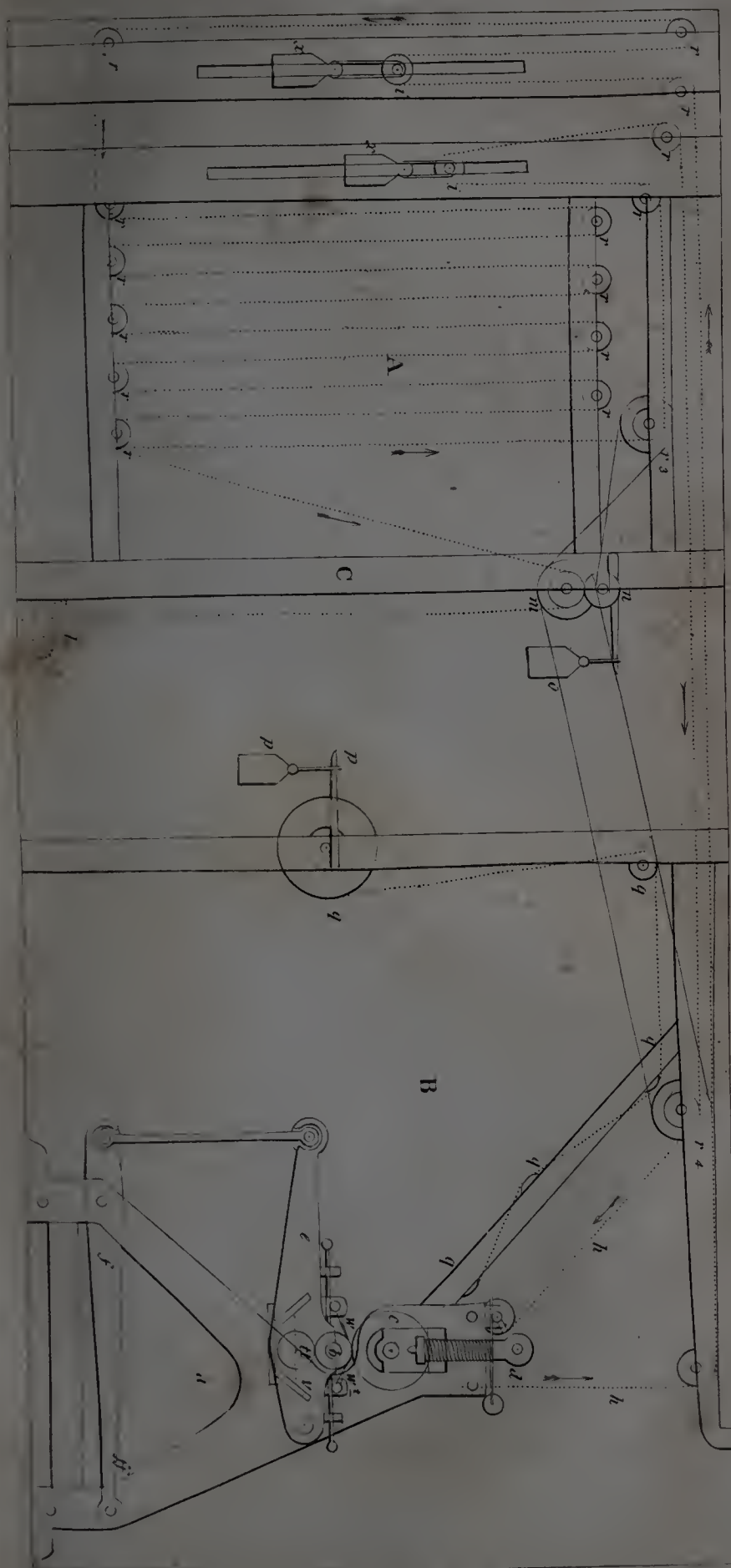


Fig. 187.

levers which are situated just within the sides or cheeks of the machine; t, for convenience of description, are represented as though seen through frame or sides of the machine; the weight is applied at *ff*, and this com- ned leverage is brought to operate upon the mandril *b*, pressing the copper ler with great force upwards against the large iron roller *c*. I have said that er the calico is passed through the machine, the iron roller is pressed down on the copper roller; but such is the force with which the machine operates, t were there nothing but the calico interposed between the two metallic llers, the calico would be cut asunder in the operation, and the engraving ned, perhaps, in a single revolution of the copper roller; to prevent this iron roller is previously wound round with from 20 to 30 thicknesses of a ong twilled woollen cloth, which is called by the machine printer the *lap- g*, which protects both the calico and the copper roller from injury, and also ves another important purpose, that of pressing, in consequence of its elas- property, the calico into the engraved figure, and thereby producing a clear- ss and fulness of impression, which it would otherwise be impossible to ef- t. It will be observed, that the furnishing roller below, and the iron ler above the copper roller, are both driven by the latter by the mere force friction, and that through them motion is given to all other parts of the ma- ine; the cloth is unwound from the roller *q*, and carried through the ma- ine, the copper roller is successively supplied with colours, and its plane sur- ce cleared of superfluous mordant, and the impression produced on the cloth thout any essential aid from the printer, except to supply the colour box with e paste, and see to the correct performance of the machine: *w* 2 is a second ctor, placed in front of the machine, (and opposite the *cleaning* doctor, so lled,) the object of which is to detach from the copper roller small bits of t which it contracts from the cloth, and thereby to prevent their mixing with e paste, and form an obstacle to the correct performance of the cleaning doc- r, by getting between it and the roller.

The doctors have a lateral motion of about three-quarters of an inch on the ller, the object of which is to prevent the unequal wear of the roller in con- quence of any unequal hardness in the roller: in consequence of this lateral otion, any given point on the edge of the roller describes a waving or lateral- undulating line, instead of a circular course round it. Then the colour or ste contains matters that act on steel, as the salts of copper in the reserve astes and other similar articles, brass or other composition doctors are used in eir stead.

Such are the arrangements *essential* to the mere act of producing an impres- on with the printing machine for the moment; but, in order to a sustained peration of it, some important appendages are necessary, which remain to be scribed. From the difficulty of entering the cloth in the machine, so that it hall constantly cover the same space on the copper roller, as well as from the ariable width of the pieces, which produces the same result, it is necessary to rnish a wider space on the engraved roller than the cloth will actually cover, nd, in consequence of this, were there nothing interposed to prevent it, the pping of the iron roller without the margin of the calico would soon become logged with colour, and would constantly endanger the calico by spreading pon it on the one side or the other, and render it impossible to proceed with- ut spoiling the work, for it must be recollected that every impression of the nordant, whether accidentally or purposely made, will produce a correspond- ng colour in dyeing in the madder bath, (on the supposition of printing for his style of work.) To obviate this difficulty an *endless* blanket (so called) f firm woollen cloth, whose circumference shall be about fifty yards, is made o pass through the machine between the calico and the lapping of the iron oller; the two parts of the blanket, as it goes to and leaves the machine, is hown in the dotted lines *h h*, and its course as propelled, or rather drawn by he machine, is indicated by arrows; taking the ascending part, the eye can asily trace it through the partition wall, *C*, into the stoving room, and thence ver numerous rollers till it arrives at the back of the machine, where it joins he calico again, and passes on with it through the stoving room to the last of the

rollers designated by *r*, where the calico leaves the blanket, and arrives by a shorter course, *k*, through the drawing rollers, *n m*, to the machine room, and falls down upon the floor at *l*: the object of this arrangement is obviously to dry the paste both on the calico and on the blanket; in the first case, to prevent the mordant, by touching the unprinted parts of the cloth, from soiling them, and to fix it by the evaporation of the moisture, and, perhaps, a portion of the acid more intimately upon the cloth; and, in the second place, to dry the paste upon the blanket to prevent its attaching to the calico; the blanket should be from four to six inches wider than the calico, or wide enough to cover the whole of the engraved part of the roller: *i i* are the tightening rollers, the gudgeons of which slide up and down in the mortices of two upright posts or standards: these rollers are weighted at each end, *x x*, sufficiently to keep the blanket in a state of equable tension, and to take up what it may stretch in length in the operation of printing: it will be observed, that one of these tightening rollers is applied to the part of the blanket soon after its entrance into the chamber, and the other to the part about to return from it; the latter roller only is usually employed, but there is a particular advantage in having two, as the slackness of the blanket, which is frequently troublesome to the printer, generally occurs immediately before, or immediately after it enters the machine, and cannot easily be kept in a sufficient state of tension by one tightening roller only placed at any part of the circuit, which the blanket describes. All the rollers and other fixtures in the stoving room should be fire proof; the rollers should be constructed of sheet copper, with iron gudgeons, and the room itself should have nothing in its structure of a combustible nature. The frame work which supports the rollers is represented unnecessarily heavy for iron, but in all other respects the drawing is correct. The drawing rollers, *n m*, are carried by a belt running from a pulley attached to *m*, and another attached to *r* 3, or *r* 4, at the pleasure or convenience of the printer. The roller *n* is pressed upon the roller *m* by levers, resting upon each gudgeon and weighted at *o*.

It is not often that so great a length of blanket is absolutely necessary, and in most cases (that is, in light and medium figures) two pairs of the rollers, designated by *r*, may be dispensed with. Some printers prefer a second set of light rollers for the calico to run upon, so as to keep it separated from the blanket through its whole course after it leaves the machine; this admits the air more freely to the back as well as the face side of the blanket, and expedites the drying process.

The best method of treating the stoving room is by horizontal brick flues with cast iron tops,—the same in all respects as recommended by the writer for drying rooms under that article in this work.

The art of printing by the machine is purely mechanical, and any intelligent machinest may acquire a competent knowledge of it in a short time.

The gearing for driving the machine is omitted in the plate to avoid complicating the more essential, or rather the more peculiar parts of the machine; the skilful machinest will find no difficulty in applying the common principles of his art to this object. It is usual to gear the machine for two motions. The slowest speed should be sufficient to print a piece of twenty-eight yards in four minutes, and the fastest in two and a half minutes.

The entire cost of a machine like the one represented, including the gearing and fixtures in the stoving room, may be about eight hundred dollars.

## *Padding.*

The object of padding is to cover the calico uniformly with a mordant preparatory either to printing a *discharge* upon it previously to dyeing, or a secondary colour, or discharge, or both, after dyeing. If this were attempted by dipping the cloth in the liquid mordant, squeezing and drying in the usual way of drying wet cloth, by hanging in the air, the larger por

ns of the mordant would subside into the most dependent
ts of the cloth before its solvent were evaporated, and cause
ery unequal deposition of the mordant upon the fabric, which
course would be followed by corresponding variations in the
de of colour after dyeing. To obviate this difficulty, the
th is passed first through the liquid mordant, then squeezed
rd between two metallic rollers, and dried in the stoving room
speedily as possible, consistently with the nature of the mor-
nt and the safety of the cloth. The machine for this purpose
quite similar to the single coloured printing machine just de-
ibed, with the exception of leaving out the *doctors* and the
*rnishing roller*, and substituting for the latter a small wooden
ller, which is placed near the bottom of the box in which the
uid for padding is put, and around which the cloth is passed
fore it enters between the rollers: indeed, in small works it
not unusual to pad with the single coloured machine. In this
eration both rollers are plane, and both are lapped with cloth
ecisely in the manner in which the iron roller is lapped for
inting, only fewer turns are necessary. Some prefer cot-
n to woollen cloth for lapping; for padding for light shades of
lour, I prefer the former, but for the deepest shades the lat-
r is preferable, owing to its greater elasticity and its superior
pacity for the liquid, by which calico is more fully impreg-
ted with the colour. The quantity of mordant left in the
oth depends also, in some measure, upon the pressure under
hich the rollers are worked. The cloth is dried after pad-
ng, in the same manner as after printing by the machine;
ving, however, to the greater quantity of moisture to be eva-
orated, the temperature must be somewhat higher, and the
me of exposure somewhat longer than in printing. It is bet-
r, also, if the rollers be so arranged in the stoving room, that
e calico in passing from one roller to another shall run in a
orizontal instead of a perpendicular direction as represented in
g. 237. This arrangement is in no respect less convenient for
rying after machine printing.

When padded cloth is dyed up, the colour will be a shade
eeper on the side of the calico which runs in contact with the
wer roller, or rather on the underside of the cloth, as it passes
om the machine to the stoving room, owing to the partial sub-
dence of the liquid to that surface before the liquid part of the
ordant is evaporated.

In the foregoing remarks on machine printing and padding,
nd in the plate explanatory of the former, I have departed from
he plan proposed at the commencement of this article on cali-
o printing, which was to treat only of the chemical and not of
he mechanical part of the art, but the processes of machine

printing and padding are of such cardinal importance in the
and so often referred to in the following pages, as to ren[der] t
short digression from the main purpose and plan of the t[ext]
almost indispensable; but, not to deviate farther from m[y]
cipal object, the reader is referred for a plate and descri[p]tion
the padding machine to Dr. Ure's Translation of Bert[hol]
Elements of Dyeing and Bleaching.

*Influence of Temperature on the Aluminous Mordant*

I have already alluded to a singular property of the solut[ion]
of the acetate of alumine in water,—that of precipitating a p[art]
of its base at a high temperature, and redissolving it again w[hen]
cold; owing to this property this mordant should be printed
as low a temperature as possible; the reason is obvious. t[he]
more gradually and slowly the cloth is dried, the more perfe[ctly]
ly will the mordant have penetrated the fabric before the liqu[id]
which holds the aluminous base in solution, shall have been d[is]
sipated, and even before any portion of the base shall have be[en]
precipitated in an insoluble state from its proper union with
acid. I think it may be asserted as an axiom in the art, t[hat]
the lower the temperature at which the printers' alumin[ous]
mordant is applied, and dried, the brighter will be the col[our]
on dyeing in madder; a very marked difference is observ[ed]
between two pieces of calico printed with the same mord[ant]
the one dried at the temperature of 150°, and the other 2[12]
Fahr. I would recommend in no case, in printing or padd[ing]
with this mordant, to expose the goods to a higher temperat[ure]
than 150° or 180° Fahr. at the most; and, where the figure
light, and will admit of it, a still lower temperature is desira[ble]

*Ageing Printed Goods.*

After the cloth has been printed with either the aluminous
iron mordant, it is usual to hang them up exposed to the action
the air for a few days before they are carried to the dye-hous[e]
and this process is termed by the workmen *ageing*. Goo[ds]
printed with the aluminous mordant are generally *aged* three
four, and those with the iron mordant from six to eight, or ev[en]
ten days. The utility of this practice on cloths, printed wi[th]
the first mordant, is, at least, questionable. I have never be[en]
able to distinguish any difference in the result, whether the clo[th]
was dyed immediately after printing or after an exposure to th[e]
air. The theory deduced from the experiments of Thenar[d]
and Roard * is, that after printing a portion of the acetic ac[id]

* Vide note B to page 73, vol. i. of Ure's Translation of Berthollet's wo[rk]
on Dyeing.

apes from the aluminous salt on exposure to the air, and that e remainder of the acid forms with the alumine a sub-salt th excess of base, which, being less soluble in water, is not so ble to wash out in the dyeing process before the alumine is ed by a chemical union with the colouring particles of the dder. That a portion of the acetic acid evaporates, or flies from the mordant after printing, is abundantly established by e observation of every calico printer, and it is not improbable t a more careful examination than I have given to this sub- t, may establish the justness of the theory to some small ex- t; but the learner may be assured that, practically, it may be ogether disregarded without loss.

With regard to the iron mordant this process is of great uti- y and importance. If cloth be dyed up in madder immediate- after printing with the mordant for black, we obtain a purple arcely equal to that produced by equal parts of the standard mor- nt and water, and which has been exposed a week to the air. he acetate of iron when printed upon cloth appears to undergo partial decomposition, an absorption of air takes place, con- rting the protoxide into a peroxide, and precipitating it upon e cloth, and a part of the acid escapes in a volatile form. The maining portion of the acid probably remains in the fabric ited with a part of the iron as a peracetate. It is a good rule allow all goods printed with the iron mordant to age one eek; the change, which follows after that period, is very gra- al, and, indeed, scarcely appreciable. The lighter shades of lour produced by the iron mordant, and also those shades of lour, into the composition of which the iron mordant enters, ay be dyed up in less time, and, in fact, without any ageing, ovided the iron be increased in quantity equal to the differ- ce produced in the depth of colour by the usual exposure to e air: in other words, the depth of colour, to a certain ex- nt, is, so far as the iron mordant is concerned, in the com- ound ratio of the strength (concentration) of the mordant, and e time it has been exposed to the air. It is, however, always safer course to mix all colours containing this mordant on the pposition of a week's *ageing;* for it is frequently impossible, a large work in particular, to dye the printed goods on the ery day required by this practice, and a single day's difference *age* will make a very perceptible difference in the shade of olour. It is the opinion of some printers that purples are righter when the printed goods are hanged in a cool room; at is, in a room not artificially heated, though the more com- on practice of printers has been to hang in rooms heated to 0° or 85° Fahr. The decomposition of the acetate of iron and he oxidation of the metal is more rapid at a high than at a low

temperature; but I have never been able to detect any other diff rence of effect. A dry atmosphere is, however, of the utmost ir portance, both as it respects the iron and the aluminous mordar and more particularly the former, to prevent the colours fro spreading. In lowery wet weather, artificial heat is indispens ble. For the same reason, great caution ought always to be use that the cloth is perfectly dry before printing; if it be damp th impression will appear much more full on some parts than o others after dyeing, and exhibit a clouded appearance; the c lour will spread most upon those parts which are most damp This uneven appearance is similar to, and not unfrequently con founded with, that produced by uneven *lapping* of the *tab roller* of the printing machine, and the machine printer is some times blamed wrongfully. The two cases may generally b distinguished from each other by observing that, where the un evenness is owing to uneven *lapping*, the dark and light spo repeat at regular intervals, but where it is attributable to damp ness, no such repetition is observable. The effects of a dam cloth is the same on the block as the cylinder work.

## *The Dunging.*

This operation consists in passing the printed calico, after has received sufficient *age*, through a hot solution or mixture cow dung in water, and washing the goods intermediately. is one of the most important in calico printing, requiring gre care and judgment to accommodate it to constantly varying ci cumstances. Goods are more frequently injured in this than any other stage of the art; and errors committed here are oft the source of miscarriages, which are unsuspectingly attribute to the colour mixer, the machine printer, the madder dyer, an almost every thing but the true cause.

The prime object and effect of this operation is to prever the printed mordant from spreading in the subsequent dyein bath, and thereby producing a colour where none was intended The theory of the operation is not well understood, and ha been variously explained by different writers; some attribute t the dung a mechanical effect merely, that of entangling and en veloping the loose parts of the mordant, and preventing thei attachment to the unmordanted parts of the cloth; others hav ascribed to the dung the chemical property of neutralizing th action of the superfluous and uncombined mordant; others, again attribute to it an effect analogous to that of oil in the *Turke Red* process, which is supposed to form a ternary combinatio with the cloth and the colouring particles of the madder. Th latter is the opinion of Dr. Bancroft, and it accords best with m own observation. From repeated experiments, I can affirm wit

nfidence that the operation of the dung is not limited merely the single effect of neutralizing the uncombined mordant. It rtainly does, where performed under the most favourable cir- mstances, exalt the madder colours; the utility of it is not nfined to preserving the white grounds in *topical* dyeing; it highly beneficial on goods that have been *paddled;* that is, holly covered with the iron or aluminous mordant, or with a ixture of both, where there is no white ground to protect. A ry marked difference will be observed between the depth and auty of two pieces previously soaked in the aluminous mor- nt, the one of which has been subjected to the usual dunging ocess, and the other not, and both dyed in the same madder th; the dunged piece will show a decided superiority. A hot ater bath will, in some cases, answer in a degree the purposes the dung bath on the iron mordant, but its effects on the alu- inous mordant are positively injurious. It cannot be denied, owever, that the primary object of the dunging operation is, most cases, to preserve the ground from contamination, and hat in securing this object we are frequently under the neces- ty of employing a temperature that more than counterbalances e benefit to be derived from the *specific* action of the dung.

The success of this operation depends a good deal upon the anner in which the goods are *entered* into the dung liquor; if e cloth enter in folds, or one part of the face side of the cloth e allowed to touch another part at the moment of entering the quor, the work is sure to be spoiled; or, if a part that has en- ered the liquor, and become wetted, be suddenly withdrawn, he colour will be liable to be uneven, and the whites bad. To bviate these difficulties, the *fly winch* is now always used for he first dunging, by which the cloth is made to pass evenly ver a number of wooden rollers attached to a frame, which is mmersed in the dung liquor; the printed cloth is rolled evenly pon a hollow cylinder, which is slipped upon an iron shaft at he entrance of the cistern, and to which a friction lever is at- ached to prevent its unwinding of itself; at the other end of the istern are two wooden *drawing rollers*, to the under one of which a pulley is attached, by means of which the power is ap- plied to draw the cloth through the cistern. The number of ollers, and speed, should be so adjusted that the cloth may be exposed to the action of the liquor about two minutes. From he fly dung cistern, the goods are dropped into a cistern of cold water, where they are partially cleansed, and thence to the dash wheel, in which they are thoroughly washed; they are hen dunged a second time, by simply winding them in a com- mon cistern containing the mixture,—rinsed in clean water, *edged up*, (that is, pulled over from end to end by one selvage,

in order to shake out the folds,) and washed again in the c wheel. If the work be heavy, (that is, if the quantity of mordant be considerable, as in heavy block work,) it is quently advisable to repeat a third time the drying, and rins and washing course.

The quantity of dung required depends very much upon amount of printed surface, and the strength of the mord For common *machine* work, 10 bushels to every 100 pie will be found sufficient for each dunging;—for heavy blotche 15 bushels, and where a larger quantity is required it is bet to dung a third time with these last quantities. A calico pr tery, designed to turn off 300 pieces of madder work per d will require the dung of 100 cows. The average quantity p duced by a common sized cow is one bushel per day. T freezing of dung does not appear to injure its qualities for t purposes of the calico printer; neither does there appear to any essential difference between that which is recently laid a that which has been kept in heaps 10 or 15 days in warm we ther; how long it will retain its useful properties I am unal to say.

The temperature of the dung bath is a matter of great i portance to the success of the operation. For madder reds a pinks the fly dung cistern should not exceed 160° Fahr., t the 2d (and 3d, if used,) 140°; too high a temperature imp verishes the reds. This effect is not attributable to the c dung, but to the solvent power of the water: it appears fr the interesting experiments of Thenard and Roard, on the fects of several mordants on vegetable and animal substance and among them of alum and the acetate of alumine, (vi note B, page 73, vol. i. to Ure's Translation of Berthollet Elements of Dyeing,) "That in aluming all vegetable and an mal substances, it is not the alumine which combines with them but the entire alum;" that from cloth thus impregnated, it easy by washings in water to dissolve out the alum entirely, an recover it from the solution in the crystalline state; "that th acetate of alumine combines also in its entire state with silk wool, cotton, and thread; that this compound retains its aci but feebly, and loses a portion of it by simple exposure to th air; and that it is then changed into acid acetate of alumine which may be dissolved out by water, and into alumine, whic remains upon the stuffs." The object, therefore, is to dun cloths printed with the aluminous mordant at as low a tempera ture as possible consistent with the attainment of the specifi

* This term is applied to heavy block work where the figure covers a co siderable portion of the surface of the cloth. Smaller figures are called *peg*

ject of this process. Another effect of a higher temperature an that directed is to sadden the colour of reds and pinks; is effect is most probably owing to the union of the mordant th some colouring principle in the dung itself.

Chocolates and purples may be dunged the first time at 170° 175°, and the 2d and 3d at 160° or 165°, and blacks at or ar a boiling heat. Reds, pinks, and light colours should ne- r be dunged after blacks, purples, or any colour containing e iron mordant, without changing the liquor and thoroughly eansing the cistern; the reverse, however, may be practised. here there is a variety of work in hand, the usual course is dung the reds and pinks first in the morning, then to reple- sh the cistern with dung without drawing off the liquor, and ng the dark colours. Care should be taken at the commencing the dunging, that the cow dung be thoroughly beat up and ixed with the water, and the cistern should be stirred up from e bottom frequently during the operation. When the useful operties of the dung are exhausted, the liquor will exhibit a rdled appearance upon the surface, which cannot easily be staken. No bad effect can result from using too much dung. he dung cisterns should be emptied of their contents at least ce a day, and well cleansed, otherwise it will be impossible preserve the whites.

If the dunging be conducted at too low a temperature, or too pidly, the mordant will *start*, as the workmen's phrase is, d run into the whites, but the evil will not be discovered till e goods are dyed; a lesser degree of the same evil is an unu- al *fulness* of the impression, which may be mistaken for a milar appearance produced by printing with too thin a paste, by *ageing* in a damp atmosphere; it may, however, be dis- guished from either of the two last effects by observing that, here the starting, or spreading, is owing to imperfect dunging, e defect will be most marked in the heavier parts of the pat- rn, whereas, in the other cases, the whole figure will partake the defect. Printers may often skilfully avail themselves of is process to remedy the mistakes of the machine printer; if e impression be too *full* the cloth should be dunged at a higher mperature than directed above; if the printing be too *bare*, e defect may be obviated to a considerable extent by dunging a lower heat, which will allow the mordant to spread a little. nother effect of imperfect dunging, is a freckled and uneven pearance on the heaviest parts of a pattern; sometimes a shaded ripe will appear lightest where the engraving was actually deep- t, and where, of course, the greatest quantity of mordant has en applied; again, we sometimes observe in blocked work a ghter shade at the joining of the blocks, where there has, in

fact, been a lapping of the impression, and where, other th equal, we should expect the deepest shade of colour. The son of these effects is obvious,—the dung liquor not having netrated through the paste, where it is applied in the grea quantity, less of the mordant is fixed upon the cloth than on lighter parts of the pattern, and not being fixed, is dissolved in the dyeing process.

### *Maddering.*

After the calico has been dunged and washed the last ti they are ready for the madder dye, and the sooner they are in the better, though no injury will result from lying in mo rate sized heaps for thirty-six hours, unless from fermentat during the extreme heat of summer, in which case they keep better in a cistern of cold water.

The exact form, or size of a cistern, or copper for mad dyeing is of no importance. A cistern 5½ feet long, 3½ f deep, and 3½ feet wide, which is, perhaps, the most conveni form, will dye 10 pieces at a time, and may be filled about o third full of water; into this break the madder, (which I supp to be the ground madder,) and introduce the goods, connect every two pieces (at both ends if the winches are worked power, but only at one end, if worked by hand,) in the u way over the winch. As soon as the goods are entered, winching process should commence, and be continued w out intermission till the dyeing is completed. The heat sh be applied the moment the goods are put into the copper,* gradually raised till the boiling temperature is attained. T dyeing may be completed in one, two, three, or more hours. the pleasure of the operator; but the more gradually the heat raised, and the more time is occupied in the dyeing, the deep and brighter will be the colour produced; this remark is perha applicable in a degree to all madder colours, but more particular to reds. Madder appears to contain two distinct colouring pr ciples; a *bright red*, which is the part which is alone valuat for the dyers' uses, and a *brownish yellow* matter, called by t French *fauve*, which it is the especial object of the dyer avoid; both of these colouring matters have an attraction for t aluminous mordant, and, of course, both have a tendency unite with the fabric in the process of dyeing; but, fortunatel their habitudes are sufficiently different to enable the dyer

* The direction in Berthollet's Elements of the Art of Dyeing, to mix t madder with water at a boiling temperature or "hot," (which I suppose mea the same thing,) is altogether at variance with the views of the best practi dyers at the present day.—Vide Ure's Trans. vol. ii. p. 116.

arate them in a considerable degree in the common operation dyeing; the yellow matter is not so soluble in water as the at a low temperature; by using, therefore, a little excess of dder, and raising the heat of the dyeing bath very gradually, mordant may be mostly appropriated by the red particles to exclusion of the degrading *fauve*. Another difference be-en these two principles is, that the yellow matter is more uble in soaps and alkalies, and does not attach itself so per-nently to the cotton as the red does, a circumstance which dyers of the Turkey red avail themselves of, together with t already mentioned, to produce a red of great beauty; the rkey reds are steeped, after dyeing, in a hot solution of soap water, which removes the brownish yellow particles, but ves only to brighten the red;* but I shall treat more particu-ly of the Turkey red process a little farther on.

Most *plates*, (that is, cylinder work,) of medium sized fig-es, on a light ground, may be brought up to a boiling heat from one to one and a half hour, for common block work o hours may be occupied; for still heavier work, that is, for avy block work, and in other cases, where the surface of the th is mostly covered, as in those styles in which the cloth has en in the first instance altogether covered with the mordant, d small portions only discharged by printing an acid upon it, it better to dye twice; at the first dyeing use about one-third the antity of madder required for dyeing a full colour, bring up e heat in one hour to 180° Fahr., then draw off the liquor, plenish the cistern with water and the remainder of the mad-r, rinse, *edge up*, wash, and return the goods to the bath, hich may be brought up to a boil in one and a half hour more; deed, for such styles it is almost impossible in the usual mode dyeing to obtain an even ground without twice dyeing; the th necessarily falls into folds, and the parts are unequally ex-sed to the action of the dye; if no more pieces were dyed at time than what could be evenly spread upon the winch, the cessity of two operations would cease, but such an arrange-ent would involve a greater amount of labour than the one re-mmended.

Another reason for raising the temperature of the madder th very slowly has already been anticipated, in part, in treat-g of the dunging process; the whole of the alum, and a part the acetate of alumine of the red mordant, being in an unde-

* Berthollet very improperly recommends "adding a little potash the moment e madder is put into the copper, by which he observes the colouring matter more easily extracted, and the colours more speedily raised," which is all true; t then the colours will be deteriorated in the same proportion.—Vide Ure's ranslation, vol. ii. p. 117, of Elements, &c.

composed and soluble state, is liable to be removed from cloth by a sudden rise of the temperature of the dying bath fore the colouring matter has exerted its peculiar action in c bining with and fixing it upon the cloth.

It is a rule with most madder dyers and calico printers boil the calico fifteen minutes at the close of the dyeing; the propriety of the practice is very questionable. Berthc directs that the bath be brought to the point of ebullition, expressly affirms that "the colouring matter is spoiled by e lition." Dr. Bancroft is of a similar opinion, and doubts expediency of using a higher temperature than can be bo by the hand; he suggests that, *if* there is any advantage i higher temperature in rendering the colour more fast, the go should be removed to a cistern of clean boiling water, and bo there. There may be supposed a little economy in this p tice of boiling, inasmuch as it is probable that more colou matter is extracted from the madder by this means than cc otherwise be done; but this colouring matter is of the gro kind, a little of the red with a very large portion of the grading brown and yellow, which it is a principal object the dyer to avoid, combining with the cloth. Another grea jection to the practice, is the dinginess it gives to the wh which it is difficult wholly to remove without essentially ir verishing the colours we wish to preserve; in short, both t ry and the observation of the best practical dyers are decid against it, and it is only remarkable that a practice so muc variance with all we know of the properties of madder sh still be pursued by any.

The quantity of madder required in any given case must pend mainly on the depth of the shade intended, and the portion of surface covered with the mordant, though so thing must be allowed for the colouring matter absorbed, the time, by the unmordanted part of the cloth. The lightest patterns may be dyed a full red, or black, with 8 lb 10 pieces * of the best Dutch crop madder; the *average* q tity for cylinder patterns may be about double that amount; for dyeing up a full colour on a padded piece, (that is, one wl is wholly covered with the mordant,) 4 lbs. will be requi Great savings may be made in a large work by carefully as taining, where a new pattern is introduced, the exact quan of madder, which may be necessary to dye it up; so, whe new lot, or even a new cask, of madder is opened, the utr pains should be taken to compare it with previous lots of kn

* Reference is here, and in all other cases in this article, where this te used, had to pieces 26 inches wide in the *gray* (unbleached) state.

rength. These trials may be safely made, in the large way, ithout any essential interruption of the ordinary course of ork, be sure to use little enough at first, and by the time the th has acquired a temperature of 180°, or even before, an opi- on may be formed whether more madder will be required to ing up the colour,* and, if more is wanted, it may either be ded to the bath as it is, or the copper may be emptied, the goods ashed, and the additional madder be added to a fresh bath; in e former case the temperature of the bath should be kept sta- onary from a half to three-quarters of an hour after putting in e additional madder.

The addition of about two ounces of ground Sicily sumach each pound of madder has the effect to preserve the *whites* uch clearer than they otherwise will be; the effect of sumach to sadden the madder reds when used in a larger proportion; t so small a quantity is scarcely perceptible in this respect. mach is also said to render the madder colours more stable; t that is more questionable.

Dr. Bancroft recommends, or would seem to recommend, on e authority of Haussman, a celebrated French dyer, the addi- n of one-fifth or one-sixth of a pound of chalk or quicklime r every pound of madder. The results of my own experi- ents are directly at variance with this result; the addition of e chalk (I did not try the lime) greatly impoverished the dye. rom this circumstance I am led to question the inference drawn om the fact as stated by Haussman, and I believe entertained y some others at this day, that natural waters, which hold the rbonate of lime in solution, are preferable for the madder ye.

A *rose* or pink hue is given to the colour of calico dyed in adder, on the aluminous mordant, by using along with the adder about double its weight of wheat bran; but the whites e much discoloured by this addition, and extremely difficult *clear*. Nearly the same effect may be obtained by dyeing a ttle weaker mordant than that used for full reds.

The addition of the salts of tin, either to the mordant or the yeing bath, is of no use whatever in madder colours, though ill practised by some old dyers and colour mixers.

As soon as the dyeing operation is completed, the pieces are rown into a cistern of cold water, where they are winched ll most of the loose madder is removed; they are then *edged p*, and well washed in the dash wheel. The next operation is

* To ascertain the state of the goods, in this respect, the best way is to cut t a small slip from the end of a piece, wash it, and winch it for a moment in weak solution of chloride of lime.

to boil them in a vessel of clean water, in which there ha be infused a pound of wheat bran for every piece, for about tw ty minutes; this is called by the workmen *branning*, aft which the pieces are again rinsed, washed in the wheel, a *squeezed*, to prepare them for the last course of work in t wet way, which, in the technical language of the art, is call the *chemicking*, and which consists in winching the goods in weak solution of chloride of lime. To prepare this liquo make in the first instance a solution of bleaching powder of o pound to the gallon. If the bleaching powder be of g goo quality the liquor will have a specific gravity of 5° T. Take o gallon of this solution, and add it to 200 gallons of water, a heat the bath to 100° Fahr.; this quantity of the solution is su ficient for ten pieces, which should be winched two at a time the bath backwards and forwards the length of the piece abo ten times. The moment the pieces are removed from this bat they should be plunged into clean water, rinsed, and, immed ately after, washed in the wheel again and squeezed; whe they are prepared for drying, and finishing for the market, u less other colours are to be applied. When ten pieces are don another gallon of the solution of bleaching powder may be a ed to the bath, ten pieces more entered, and so on, till fi pieces have been done; when the liquor of the bath should thrown away, and the cistern replenished as at the beginning

It scarcely need be said that the object of the two last pr cesses is to clear the whites from the colouring matters contra ed in the dyeing bath, and the directions as to the quantities bran and bleaching powder are to be considered merely as g neral rules for the workman, subject to great exceptions corre ponding with the difficulties to be overcome; sometim s th whites are so little discoloured in the bath that a single ra ning is sufficient to *clear* them perfectly, and the solution o bleaching powder may be omitted altogether; at other time both operations require repeating; these differences are de pendent on the bleaching, the qualities of madder, the tem perature used in dyeing, the dunging, and other causes, som of which have already been noticed, and others remain to b pointed out. In general the colours dyed exclusively on th iron mordant, blacks and purples, come out of the madde bath with the clearest whites; reds have the whites more disc loured; and, what may appear singular, chocolates and other co lours, dyed on a mixture of the iron and aluminous mordant have the unprinted parts most discoloured, and most difficult t clear; this last circumstance is probably owing to the superio attraction of the aluminous base for the colouring particles, i consequence of which it appropriates the first that are dissolve

y the water, and partially suspends the operation of the iron ordant, which is in the mean time partly dissolved and fixed on the whites.

It has long been the practice of many calico printers to use, stead of the solution of chloride of lime recommended above, solution of a chlorate, (or *oxymuriate*, as it was formerly lled,) of soda or potash. To prepare this liquor, add to a so- tion of chloride of lime in water, (one pound to the gallon,) 5° T., ten ounces of the sal soda of the shops, or six ounces commercial potash; stir the mixture for a few minutes; when e lime has subsided, decant the clear solution, which is called y the workmen *clearing liquor;** this is the celebrated *lixi- ium of Javelle* of the French bleachers, which has long since iven place to the chloride of lime in bleaching, but which is ill retained by calico printers, under the idea that its opera- on is more mild, and that the lime in the latter has an injuri- us effect on madder *reds*. It certainly does not act so quick- as the solution of chloride of lime, but with suitable care the tter is equally manageable, and I have never been able to per- ceive any difference whatever in the effect produced on the mad- er colours by these two preparations. If my own observa- ons are correct, therefore, the difference in the cost of these vo solutions should determine a preference in favour of the mple chloride of lime. This operation of clearing the whites y the action of chlorine, whichever of the two preparations e used, is a very delicate one, and should be committed to a erson of care and judgment. If the operation be too severe he colours may be essentially impaired. When the goods are eady for this process, if there be any material differences (as here frequently will be) in the amount of discoloration of the whites, the pieces should be carefully assorted into two or more lasses, as the case may require, and the time of immersion pro- portioned to the obstructions to be removed. Where the whites re very dingy, I have found an advantage in adding to the so- ution of chloride of lime a small quantity of muriatic acid, (say n the proportion of 2 or 3 oz. to every 10 pieces,) this appears o answer better than to increase the strength of the clearing iquor by the use of more chloride of lime; and muriatic acid s better for this purpose than the sulphuric.

The *copper coloured spots*, which are frequently observed n the whites of goods that have been dyed in madder, and bout which there have been such a variety of opinions among vriters on this subject, as well as among practical printers, are clearly owing to the remains of oil contracted in the manufac-

* One gallon of this is used in the same way, and quantity, as a gallon of the olution of the bleaching powder without the lime.

ture, or at a subsequent time, and which has not been removed the bleaching process. (Vide "Bleaching for Calico Printin in this work.)

The pale cherry red stains, which sometimes involve t whole unmordanted surface of the piece, are also attributable imperfect bleaching. In this case there seems to remain in t cloth some *natural* principle, which has the effect to fix tc certain extent the red colouring matter of the madder. V hear, however, much less complaint of these difficulties, a particularly of the former, since the general introduction of li into the bleaching process.

It has often been asserted, that cloth which will receive w ter evenly, when the cloth passed through it, will dye well madder, and afford good whites, and the same test of the fitn of cloth for madder colours has been proposed as for the rec tion of the indigo dye;* but nothing is more untrue. For nately we have a very easy test, and that is in madder itse the process is this:—winch the bleached pieces a few minu in a very weak and warm decoction of madder, (the liquor a spent madder bath will answer every purpose,) and afterwa wash them well in the dash wheel; on pulling these pieces o a rail, between the eye and the light of a window, there v appear a slight discoloration of the whole surface; but, if reddish, nor copper-coloured, or orange spots be observed, dyer may rest assured that the bleaching has been effectual, nothing is to be apprehended from that source in the mad bath: if, on the other hand, such stains are observed, in slightest degree, he may be assured that they will become dee in the usual process of maddering, and rob him of the satisf tion of producing good work. Some printers are so particu in their work, as to test every piece in this way before printi others content themselves with trying a few pieces from eve bleached lot, and if no defect is observed in these, take the r on trust.

In the foregoing remarks on madder dyeing, I have referr constantly to the Dutch crop madder as a standard of compa son, and purposely deferred to this stage of this treatise the f remarks I have to offer on the varieties of this article to found in the American market. The principal sources, fr which the supplies for calico printing are derived, are Holla and France; and from these countries it is, I believe, import exclusively in the ground state. The Dutch or Zealand m der (the *Rubia Tinctorum* of Linn.) is imported under t denominations, the *Crop* and *Umbro;* the first is consider

* Vide the article "Blue Dipping" in this work.

best, and bears a considerably higher price; both are manufactured from the same root; the difference is, or ought to be, that *umbro* is made up mostly of the cortical part, which abounds most in the degrading or yellow colouring particles of this substance; and the crop chiefly from the interior of the root, which contains a larger proportion of the red matter, for which this drug is alone valuable. Formerly the Dutch made three varieties; the first was called *mor*, or *mull*, and was composed of the very outermost rind, the smallest roots, and earthy matter; the second, denominated *gort gemeen*, composed of about one-third the outermost part of the large root, and the third and last composed of the interior pure and bright part of the root; the separations were made by repeated poundings, siftings, and other mechanical means. Either these distinctions are not kept up by the cultivators, or the most inferior kinds are not invoiced to our merchants as such. The best Dutch madder is of a bright reddish yellow, and on nice inspection, even with the naked eye, will be found to abound in minute particles of a very bright red colour; it has an acrid sweetish taste, and is cemented together in casks in a very compact form, so much so that after the cask is destroyed the contents can only be severed by repeated blows of an axe; I have never met with a cask of madder, having all these properties, of an inferior quality; on the other hand, I have never known a cask of Dutch madder of a dark brown colour, and a soft consistence, that was worth using; between these two descriptions we meet with a great variety of qualities. The value of this article, of course, depends entirely upon the quantity of red colouring matter which it possesses. A very near approximation may be made to the comparative value of different samples, by the following experiment, founded on the solubility of the colouring particles in water;—place thirty or forty grains of each sample, in separate piles, upon a piece of board or other flat surface; flatten these piles a little at the top by any smooth surface, and expose them to the action of a damp atmosphere in a cellar, or elsewhere, for from 12 to 24 hours; when examined, at the expiration of that time, they will be found to have attracted sufficient moisture from the atmosphere to dissolve a portion of the colouring matter, and the depth of colour of the surfaces of the piles will indicate very nearly their comparative value.

The French madder, now much used by the calico printers, is a very different article in appearance, and, in some respects, in its habitudes; it comes in much larger casks than the Dutch, is much less compact, of a dark brown or snuff colour, and in much finer powder than the latter. It is invoiced under six different marks indicating different qualities. The best quality

produces a finer red than the Dutch crop, and is now univer ly preferred by the dyers of the Turkey red in Great Brit it is inferior, however, in strength to the best *crop*, and is m liable to discolour the whites in the dyeing bath. The tw three first qualities are, alone, well suited to the purposes of calico printer, and these, at the prices they have borne in market for the last two or three years, I have found to be a tle cheaper in use than the Dutch crop. The lower quali are used, I believe, to better advantage by the woollen dy The comparative strength (in colouring matter) of different s ples may be tested in the manner already described above. French madders are the product of the genus *Rubia Peregr* of Linn., formerly imported into England exclusively from Levant, in the roots, in which form it is occasionally met w in this country.

### *Turkey Red.*

I shall conclude this article by a description of the mod French method of dyeing the Turkey or Adrianople red, wh is now universally practised in England and Scotland. For more complicated and tedious method of the old dyers, I r refer the reader to the elaborate works of Bancroft and thollet.

Take 20 lbs. of olive oil;*
20 ounces of potash;
16 gallons of water.

Dissolve the potash in half a gallon of the water; then w the oil, and add it by degrees to the remaining water, w should also be warm, and beat them together with a bundl twigs; lastly, add the solution of potash, and renew the ag tion until the whole assumes the appearance of a milk-like fl In this liquor the cloth, previously half bleached, is pad twice, and dried four consecutive times, (that is, it is pad eight times and dried four,) at a temperature not exceeding 1 or 180° Fahr. It will require about six quarts of liquor for eight paddings, *per* piece. It is then boiled half an hour solution of pearl-ash of one and a half ounce to the gallon, t winched a few minutes in hot water, and washed in the d wheel. The cloth is now prepared for the mordant, which is p pared from three pounds of alum, and two and a quarter pou of sugar of lead, to one gallon of water; if printed with the linder, the mordant is used of the full strength for a full and thickened with starch; *if padded*, for a full red, two p

* The most inferior kind of olive oil, called in commerce the Gallipoli is always used for this purpose.

the liquor are diluted with one water; for a rose pink, use mordant and five waters. After the mordant is applied, the ces are boiled in bran and water (one pound to the piece) nty minutes, rinsed, and washed in the wheel. The pieces then dyed, first in three pounds of French madder, and lve ounces of bullocks' blood to the piece; the temperature rought up to 150° or 160° Fahr. The pieces are then taken of the bath, rinsed, edged, washed, and dyed a second time four pounds of madder, and twelve ounces of blood to the ce. The temperature is brought up to a boil in the second ng in one and a half hour. The goods are then boiled three rs in the bran copper, rinsed, and washed,—exposed two s upon the grass,—boiled again in white soap, three ounces he piece,—bleached again on the grass three or four days,—ared in the oxymuriate of lime, or potash, in the usual way, vashed,—boiled again in soap, and, lastly, cleared again in oxymuriate of potash or lime. These directions apply in ir full extent to goods that are *printed*, and have whites to ar. On the *padded* pieces the use of the oxymuriate of e, or potash, the *crofting*, or bleaching on the grass, and, haps, one branning may be omitted altogether. This is sub-ntially the Turkey red process, as now practised by the best ers in England; yet, perhaps, no two pursue precisely the ne course of work, nor use exactly the same proportions of materials prescribed, and as usual an undue importance is ached by the workmen to slight variations, which do not ef-t the principles of the process. The most material point in ich this differs from the common operation of madder dye-, is in the preparation of the cloth with the alkali and oil, d the oftener this process is repeated the brighter will be the our. Some printers produce pretty good reds with only four hes padding; others, who aim at great excellence in the art, d as many as ten times. The use of the oil supersedes the cessity of dunging in this process; indeed, although cow dung ually improves the depth and beauty of common reds, yet it incompatible with the highest degree of lustre, of which the adder colour is susceptible in the Turkey red process.

### *Alkaline Solution of Alumine.*

Another mordant for reds is a solution of alumine in caustic tash. It is prepared as follows:—Dissolve three pounds of m in one quart of water, at a boiling heat; then pour into is solution two quarts of caustic potash ley at 40° T.; a dense hite precipitate of alumine is instantly produced, which must added together with the other matters of the mixture, (the ater and the sulphate, or the super-sulphate of potash,) to three

quarts more of a caustic ley of the same specific gravity as first, and at a boiling temperature (of water.) Boil the wl till reduced to one gallon, and when cold pour off the cle quor, and wash the sediment, which is a crystallized sulpl and super-sulphate of potash, with as much water as will n one gallon of clear liquor. This is the alkaline solution of mine. It is thickened with British gum. After printing, goods are hanged for 12 or 24 hours in a damp atmosph and then winched in a solution of muriate of ammonia, phate of zinc, or sulphate of magnesia. Dye in madder w out dunging.

In the first step in the foregoing process the alkali combi with the sulphuric acid of the alum, forming a super-sulpl of potash, and remains in solution; and the alumine is prec tated, (in the chemical sense of the term,) but, being very li does not readily subside. In the second step of the operati the addition of the precipitated alumine to a fresh portion of kaline ley, the alumine is redissolved, not in acid, but in potash; the reason why the whole amount of potash requ for the precipitation and solution of the alumine is not adde once is, that in that case a neutral sulphate must be form which must necessarily require more potash; and the same son obtains for the direction to add in the second step the cipitated alumine to the potash, and not the potash to the mine.

This solution of alumine is so extremely soluble in w that it cannot be fixed in the usual way that the acetate of mine is done; the moment the cloth should enter the dung quor a portion of the mordant would spread and fix upon ground, but a larger part would be dissolved and removed fr the cloth entirely; in the *fixing* process directed, the acid the salt combines with and neutralizes, and precipitates the a mine upon the fabric and the alkali, metal or earth not acting a mordant, and being incapable of dissolving the alumine, v leave it in undisturbed possession of the cloth. This solut will bear some dilution, even for the deepest reds. The al line solution of alumine is a cheaper mordant than the comm aceto-sulphate of the same earth, and I think its use should more general than it is. An opinion prevails among cal printers that it requires more madder to produce a given eff than the common red mordant; my experience does not ena me to say whether or not this opinion is well founded.

### *Padded Alkaline Pink.*

Take one gallon of the alkaline solution of alumine, as p pared above, and dilute with four or more gallons of water,

ding to the shade intended, and, to every twenty-four measures of the solution, add one of olive oil, and mix well. Pad pieces, and fix, as above directed, in sal ammoniac, sulphate zinc, or sulphate of magnesia; I prefer the first for pinks. e in madder, (French,) and brighten with soap. This will e the Turkey red hue to the colour. For common pinks the may be omitted, and the colour will then be brighter and re even than when the aceto-sulphate of alumine has been d.

If a chrome yellow is to be printed as a discharge on this ound, the goods, after fixing, and before dyeing, should be ured in a weak solution of pearl-ash (half an ounce to the lon) to remove any superfluous oil. (For a farther applicion of the alkaline solution of alumine, vide *Warwick's reen.*)

### *Of Colours Dyed with Quercitron Bark.*

The mordants for the quercitron bark (quercus nigra, or black k,) are the same as for madder colours. It is usual, however, to sighten the aluminous mordant with the quercitron bark elf, to enable the dyer to select pieces intended for this colr from those designed for the madder reds; the dyeing can o be completed in a shorter time, for, if Brazil, or peachwood used for sightening, it combines with the aluminous base, d some time is required to displace it, by the superior attracn of the bark.

The treatment of goods designed for dyeing in the quercitron rk, the thickening of the colour, the printing, the ageing, dung-g, &c., whether printed with the aluminous or the iron mornt, is the same as for the madder dye, with the exception that is not often necessary to dung the pieces but once for those lours, of which the iron mordant is the base.

With the aceto-sulphate of alumine at 18° T., prepared from gar of lead and alum, the bark affords a full bright yellow hen printed with the block, and for lighter shades will bear a lution with from two to three waters. This liquor is always be preferred to the same mordant prepared from the pyroligate of lime and alum, which never affords so bright a colour. he aluminous mordant is seldom printed by the cylinder for ellows.

Iron liquor at 18° T., printed with the cylinder, affords with uercitron bark a dark greenish brown, or bottle green; at 12° ., a light drab. The same mordant, at 18° T., produces with he block almost a black; and, with one to four, or five waters, arious shades of drab. Mixtures of the iron and aluminous ordant, in different proportions, produce various shades of

olive, from a yellowish green to a greenish yellow, accor as the iron or aluminous base predominates, and the am dilution of one or both.

The dyeing of yellow with quercitron bark is a very s and expeditious process. Three pounds of the ground bar sufficient to dye a padded piece of a full yellow; but as th a cheap drug, and an excess will enable the dyer to operate lower temperature, and, to expedite the process, it is us use in all cases, at least, from one and a half to two poun the piece. The goods are entered cold, and the bath is gr ally brought up to the temperature of 100° or 120° Fahr. at most. From a half to three-quarters of an hour is require complete the dyeing. The lower the temperature used, brighter, and, according to Dr. Bancroft, (to whom is due merit of introducing this valuable drug to the attention of ropean dyers,) the more permanent will be the colour. temperature approaching a scalding heat be employed, the low will not be so bright, and the grounds, or whites, wil more discoloured. To improve the beauty of this dye, o preserve the grounds from discoloration, the use of glue, cr of tartar, sumach, potash, and other substances, have been time to time proposed and used; but I purposely omit a particular notice of them, because I have ascertained that e ly good effects can be produced without them by following above simple directions; when a slight branning, and somet a washing, alone will suffice to produce the clearest ground

A peculiarly rich orange tint is given to the quercitron yellow, by adding to the dyeing bath a small quantity of l or, what is preferable, lime water, which in some styles of w is much admired.

In those styles of work having a yellow ground, a most l liant and beautiful yellow is produced by the addition of e or ten ounces of the liquid proto-muriate of tin of a spec gravity of 114° T. to the dyeing bath for every ten pie This colour is not so fast as that dyed wholly on the alu nous basis, but it is more permanent than that dyed on the mordant alone. The fashionable prints of purple figures o Canary ground, so much worn the last two or three years, their chief excellence to the uncommon delicacy of this col The goods are first printed and dyed in the usual way, in n der purple figures, then padded in the aluminous mordant f sugar of lead and alum of a specific gravity of 12° T., hot tered (not dunged) at 140° Fahr., and dyed as above describ The padding liquor is thickened with one-thirtieth part measure of gum water at 35° T. It will be obvious that tin mordant cannot be used for dying *printed* yellows wh

re is a white ground to protect, as the tin will fix a portion
the colouring matter on the grounds, and render it impossi-
to clear them without destroying also the beauty of the to-
l yellow: neither can it be used with those colours upon
ich the acid of this salt would operate as a *discharge*.

The directions given above for dyeing with bark on the ace-
sulphate of alumine are equally applicable to dyeing on the
n mordant, and on mixtures of the two mordants.

Mixtures of madder and quercitron bark, dyed on the alumi-
s mordant, produce various shades of orange, according to
proportions of each and the strength of the mordant; but,
ing to the superior depth of colour and attraction of the mad-
for the mordant, the bark must, in every case to produce
ch effect, be in considerable excess.

### *Buff Colour.*

This very simple, but fast colour, is produced by printing on
calico an acetate or sulphate of iron, and precipitating the
ide upon it by passing the cloth through a solution of potash,
milk of lime. For the roller we use the green acetate, or
her the aceto-sulphate, prepared as follows:—

Take 4 lbs. of proto-sulphate of iron;
2 lbs. of acetate of lead;
1 gallon of water.

Dissolve the copperas in the water by heat, and when the so-
tion is completed, add to it the sugar of lead, and stir the
ixture two or three minutes; then let it stand, and when the
lphate of lead has subsided, decant the clear liquor, which will
ve a specific gravity of 29° T., and thicken with flour, gum Se-
gal, or British gum. The first is most commonly used on ac-
unt of its cheapness; the two last are preferable for some pat-
rns. I have not been able to find a good material for *sight-
ing* for this colour; none of the usual vegetable colouring
atters will answer, for an obvious reason. It has been the
actice of many colour mixers to employ the Venetian red for
is purpose; but it is difficult to remove it from the cloth after-
ards. The *high dried* British gum answers in most cases
th for thickening and sightening; and where this cannot be
sed, it is, perhaps, better to do without any. This liquor, when
sed without dilution, affords what is called by the printers a
*old* colour; diluted with one, two, or more colours, different
ades of buff.

For padding light grounds, dilute the liquor with 10 to 15 wa-
rs, and thicken with about twelve ounces of gum Senegal to
ne gallon.

### *Buff Liquor for the Block.*

Take 1 gallon of water;
4 lbs. of proto-sulphate of iron;
2 oz. of concentrated sulphuric acid.

Thicken with gum Senegal. This liquor will produc strong buff, or gold colour, and for lighter shades may be luted to any amount desired. The sulphuric acid serves to k that part of the iron, which becomes converted into a peroxi from precipitating; the temperature at which the cloth is cessarily exposed, and the action of the acid on the *doctor*, f bid its use in machine printing.

Printed and padded buffs require ageing three or four da and should be hanged in a cool room, otherwise the thicken becomes so hard as to resist the penetration of the liquor in process of *raising*. There is no serious objection, howev to raising the buffs the day after printing; but the longer th hang exposed to the air, the darker will be the shade; at l they will continue to grow darker for eight or ten days.

### *Raising Buffs.*

To do this in the best manner, provide a cistern with rol precisely like that used for fly dunging, having a frame w about four pairs of rollers, over and under which the cloth conducted so as to expose the surface evenly and extensivel the action of the raising liquor; from this cistern the cl should pass directly into another cistern filled with clean wa and provided also with one or two pairs of rollers. For raising liquor, take 8 lbs. of pearl-ash and 40 lbs. of lime; the cistern so as to cover the top row of rollers, and then the pearl-ash and lime, and keep the lime suspended in the w ter, by stirring, while the cloth is passing through the liqu the speed should be such as to expose the cloth about one m nute to the action of the lime liquor. From the rinsing ciste the cloth is removed instantly to the dash wheel, well washe and *edged up;* it is then winched in a cistern of water at a te perature of 140° to 160° Fahr., washed again, squeezed, a dried *in the air.* Nothing is more simple than this operatio and yet, unless great caution be used, scarcely any one in t art is more liable to miscarriage. Whether the goods be e posed to the action of the liquor by the hand, or over rollers the manner described, the utmost care should be used, on ent ing them, not to allow any part of the cloth to touch the liqu till it is fairly immersed in it: if it be wetted by the liquor, a then suddenly withdrawn, for the shortest space of time on

colour will come out of the cistern uneven; or, if the *face* e of the cloth be allowed, on entering the liquor, to touch lf in any part, the colour is sure to be uneven; on this ac- nt, when the goods are entered by hand, the stick, which is mmonly used, should be thrust upon the *back* instead of the e side of the cloth, otherwise this accident will frequently ur. The sooner the cloth is rinsed, and washed, after the eration, the better it will be; for this purpose *straining** is t where it can conveniently be resorted to.

### *Bronse Colour.*

Take 4 lbs. of the sulphate, muriate, or acetate of manganese;
1 gallon of water.

Dissolve the salt in the water, and thicken with gum Sene- l. Pad the cloth the same day (if convenient, but no injury ll accrue from laying a day or two) in a solution of caustic kali at 10° T.; and, without drying, washing, or rinsing, winch e pieces through a solution of the chloride of lime of a speci- gravity of $1\frac{1}{4}$° T., or, of about 4 oz. to the gallon;—25 lbs. the bleaching powder to 100 gallons of water will answer 50 pieces printed in the heaviest figures; after winching that mber, the liquor should be drawn off, and a fresh solution de, otherwise the whites will be injured.

The theory of this operation is very similar to that of pro- cing the buff from the salts of iron. All the salts of manga- se have a protoxide for their base; the alkali precipitates the ide from its base, and, in the second operation, the chlorine d the oxide decomposing a portion of the water, by what che- ists have denominated a *predisposing affinity*, the hydrogen ites with the chlorine, forming muriatic acid, and the oxygen ith the protoxide of the manganese, converting it into, per- ps, a peroxide.

Where a very dark *ground* is wanted for discharging after- ards, the alkaline solution should have a specific gravity of 8° T. at 60° Fahr., and when the pieces are padded should be ept at a temperature as near a boiling heat (212°) as possible. Particular care should be used to keep the temperature as equa- le as possible, to ensure an even ground.

When it is practicable to get a sufficiently dark shade with- ut the use of the chloride of lime, it is better to omit it; for, lthough it deepens the colour, it also saddens it. Instead of winching in the chloride of lime, some printers hang the goods

* This operation consists in holding the piece by one end in a rapid current f water.

with the potash liquor in them two or three hours; th[en] w[ash] in hot water, and put through soft soap and boiling w[ater] wash again, and dry for printing.

### *A Dark Brown,*

Somewhat similar in appearance to the bronse above descr[ibed] is produced in the following manner:—

Take half a gallon of caustic potash ley at 36° T.;
1 lb. of orange orpiment.

Dissolve by heat, and then dilute the solution with half a g[al]lon more water, when the solution will mark 18° T. P[rint] the roller, and hang a few hours. Give the pieces eight or t[en] ends* in a solution of sulphuric acid in water at 2° Fahr[.] Hyd.;—rinse and wash in the wheel. Lastly, winch the pie[ces] in a solution of acetate of lead, allowing 4 oz. to the piece[s] winch in water at 180° Fahr. eight or ten minutes; w[ash] we[ll] and squeeze.

The object of these processes is to fix upon the cloth a s[ul]phuret of lead. The orpiment is a sulphuret of arsenic;—[the] effect of the sulphuric acid is to precipitate, by combining w[ith] the potash, which holds it in solution, the sulphuret upon [the] cloth in the same state as it was previous to its solution; in [the] stage of the process we have a beautiful yellow, but it will [not] bear the action of a solution of soap; the effect of the acet[ate] of lead is to produce a double decomposition,—the acetic a[cid] of the lead seizes the arsenic of the orpiment, and the sulph[ur] of this orpiment forms an insoluble sulphuret of lead. This [co]lour is very fast, and is not affected by the madder dye.

### *Chrome Yellow.*

Take 2½ lbs. of nitrate, or acetate of lead;
1 gallon of water.

Thicken, cold, with British gum. Print, and after hangi[ng] 12 hours, wet the pieces, and then winch in a solution of bichr[o]mate of potash, of 1 oz. to the gallon, for fifteen minutes;—f[or] medium sized figures, use 2 oz. of the bichromate to each piec[e] The colour will be a little deeper by wetting the pieces, prev[i]ous to chroming, in a solution of potash in water, of 2 oz. [to] the gallon, and washing; but it is cheaper to use a little strong[er] solution of lead, if a deeper shade be wanted.

In this process there is a double decomposition of the salt

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* The workmen's phrase, implying passing the pieces so many times fro[m] end to end through a liquor by means of a winch.

d and the bichromate of potash, and the result is a nitrate or etate of potash, which remains in solution, and an insoluble romate of lead, which is fixed upon the cloth. This colour ay be printed with either the block or cylinder, but is not uch practised except in connexion with certain *discharge* yles, which will be treated of by and by.

### *Chrome Orange.*

Dissolve 2 lbs. of nitrate of lead in 1 gallon of water, and icken with gum Senegal. Winch the cloth after printing in olution of sulphate of magnesia, of 1 lb. to the gallon. Raise the chromate of potash (yellow chromate) 2 oz. to the piece, d then winch the goods in boiling lime water; do not enter e pieces till the lime water boils. Perhaps alum might be adntageously substituted for the Epsom salts.

### *Prussian Blue.*

Print the cloth in the mordant for a black; age one week, and ng the pieces as for madder colours; then winch them in a lution of prussiate of potash slightly acidulated with sulphue acid. Medium figures will require about 2 oz. of prussiate potash to the piece. Some printers direct that the pieces be nched in lime water, previous to dunging, but the practice is necessary.

The theory of the formation of this colour is very simple; e prussiate (or more properly the *ferrocyanate of potash*) decomposed by the sulphuric acid, which unites with the potsh, forming sulphate of potash, and the disengaged ferrocyanic id combines directly with the peroxide of iron, forming the autiful compound, so well known as a pigment, prussian blue, the ferrocyanate of iron. This colour is unaffected by air, ater, or weak acids, but wants the most essential requisite of fast colour, that of resisting the action of alkalies and soaps.

A solution of ammoniuret of copper was for some years mafactured and sold to the calico printers in Lancashire, Engnd, by the name of the *prussian blue fixer*, but I believe s claims to that title are now questioned by the most intellient of the trade.

### *Chemical, or Spirit Colours.*

These terms, absurd as distinctive appellations, are applied those colours in which the mordant and colouring matter are ixed previously to their application to the cloth, and in geneal require no farther operation to fix them after printing. They re not so fast as those colours in which the cloth is first impressed with the mordant, and afterwards dyed, even where the

same mordants and colouring matters * are used. This dif ence is owing to two causes, one or both of which apply in o ry case;—1st, The cotton does not possess so strong an att tion for the mordant and colouring matter respectively as t do for each other; and, therefore, where the mordant and louring particles are previously united, as they must be t considerable extent before their application to the cloth, th strength of attraction is such as to exclude the effective attr tion of the cloth for them, and instead of a ternary compo of the mordant, colouring matter, and the cloth, there is a co pound of the two former merely, mechanically precipita upon the latter; 2dly, In those cases where the cloth may supposed to possess naturally as strong an attraction for the m dant and colouring matter as the latter have for each other; t attraction is rendered in a great measure ineffectual by the solubility of the compound previously formed by the latt This difficulty is, in some degree, obviated by preventing, far as possible, the union of the mordant with the vegetable louring matter by the mechanical properties of the thickenin and the manner of mixing them. In general a watery dec tion of the dye stuff is first made, and thickened with fl starch, or gum, and the mordant is added afterwards, by wh means the vegetable matter is in a degree enveloped and shi ed from the action of the mordant till both are united with cloth.

### *Chemical Black.*

Take 12 measures of a decoction of galls at 14° T., thick with flour; when cold, and about to be used, add one measu of liquid nitrate of iron at 84° T. The decoction of galls w require about 3 lbs. of nut galls to one gallon of water. Som printers use, in conjunction with the decoction of galls, a d coction of logwood; but it is unnecessary. *Age* one week ter printing, then wash, &c.

### *Chemical Black* (from Logwood.)

Boil 4 lbs. of logwood chips in two gallons of water, to o gallon; filter, and add to the clear decoction 12 oz. of sulph of copper; thicken with flour, and when cold, and about to used, add one pint of liquid nitrate of iron, at 84° T. This a cheaper colour, but not so fast as the preceding. Some d

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* By *colouring matter*, in this connexion, and in most other cases where i contrasted with the term *mordant* in this treatise, is meant merely the vege able principle, which, although it may not even possess any colour of its when united with an earthy or metallic matter, produces colour.

r mixers substitute the sulphate for the nitrate of iron in their emical black; but it does not thicken nor work as well.

### *Chemical, or Berry Yellow.*

Take one gallon of a decoction of Persian berries of a spe- c gravity of 4° T., and dissolve in it 8 oz. of alum; thicken h flour. After printing, the cloth is winched in lime water, what is called milk of lime, (that is, water made milky by icklime,) by this means the colour is rendered much brighter n it otherwise would be by precipitating and combining a ger portion of the aluminous base upon the cloth. Where s exposure to the action of the lime would injure other co- rs, previously applied, it may be dispensed with by substi- ing the aceto-sulphate of alumine for the alum. To prepare e decoction of Persian berries for the foregoing colour, take lbs. of Persian berries, and boil them in 20 gallons of water 16 hours; then strain off 13 gallons of the liquor; add to e berries 20 gallons more water, and boil 16 hours more, en the berries will have become soft and deprived of all their louring matter; strain off the remaining clear liquor (about gallons) and add it to the first.

### *Spirit Red, or Peachwood Wash-off Pink.*

Prepare a strong decoction of peachwood, in which the co- ring matter of 100 lbs. is contained in 12 gallons of water; ke one gallon of this decoction, thickened with starch or ur, one gallon of the liquid nitro-muriate of tin at 80° T., d two gallons of gum water: 4 oz. of blue vitriol is an im- ovement. Age 24 hours after printing, and then simply wash e goods. Brazil-wood abounds more in colouring matter, but thought by most printers not to yield so fine a colour. The coctions of both peachwood and Brazil-wood improve by age, cording to Dr. Bancroft. The nitro-muriate of tin should be ded to the thickened decoction when cold, and only when nted for use. This colour is very beautiful, but not fast.

### *Spirit, or Wash-off Purple.*

Take four measures of a decoction of logwood at 8° T.; thick- with starch, and when cold, and wanted for use, add one easure of liquid nitro-muriate of tin at 80° T. Print, and ng at least 24 hours before washing off. This colour, like e last, is extremely beautiful, but very fugitive.

### *Cochineal Pink.*

To one gallon of water add one pound of cochineal as fine as ur; boil half an hour, and then add 2 oz. of finely pulverized

gum dragon, and 2 oz. of cream of tartar, and stir till the wh is dissolved; when the liquor is cool, add one measure of sol tion of nitro-muriate of tin at 80° T., to two of the cochine liquor, and incorporate well by stirring. Print, and hang hours before washing off. This formula is taken, substantiall from the article "Colour Mixing" in Rees' Cyclopædia. ought rather to be called a scarlet. It is very fugitive.

By mixing the decoctions of peachwood and Persian berrie or of peachwood and quercitron bark, and of peachwood and lo wood in different proportions, and proceeding in other respec as in the three foregoing formulæ, a great variety of orang brown, purple, lilac, cinnamon, and other colours may be pr duced of great beauty; but their want of fastness precludes, ought to preclude, their use in the art. A colour depende solely on the tin basis cannot be said to be fast, in the accep tion of the term, as used by calico printers; it may, indee bear the action of acids, and repeated washings in soap and w ter, without much change, but it will not endure the action light.

### *Steam Colours*

Are those in which the mordant and colouring matter mixed, as in *chemical* colours, previous to their application the calico, but which are afterwards fixed more permanen upon the cloth by the application of steam. For this purpo a hollow cylinder of tin or copper, six or eight inches in dian ter, pierced with holes like a colander, closed at one end, a connected by a pipe at the other, with a steam boiler, is f wrapped round with several thicknesses of flannel, next with piece of unbleached calico, and then with the printed goo (say eight or ten pieces,) afterwards with a piece of gray cal again, and, lastly, with several folds more of flannel. T steam from the boiler, at a temperature somewhat above that boiling water, on turning a cock, is forcibly driven through t pipe into the cylinder, and having no other means of escap gradually penetrates the substance of and escapes in volun from its surface. Great care is required that no water rus in with the steam, as that would soften the thickening and ma the colour spread: the object of the first folds of calico a flannel is to absorb any water that may be violently projec from the steam pipe, and of the outermost folds to prevent su a loss of heat as would cause the steam to be condensed on printed calico. In this process the steam seems to produce su a partial softening of the paste as enables the chemical action take place without spreading beyond the limits of the figure the temperature is doubtless highly favourable to the exert

chemical attraction. It is, in fact, a topical dyeing. At the piration of twenty or thirty minutes the steam is stopped, the ods are unrolled, and, though reeking with steam, are per- tly dry to the touch, the sensible heat being sufficient to car- off the whole without leaving any moisture upon the calico. The high temperature employed in this operation precludes e use of the nitro-muriate, or, more properly, permuriate of , which would prove ruinous to the texture of the goods, if ployed in the manner in which it is done in the prepara- n of *chemical* colours. The mordant employed in its stead what the printers call a *double acetate of alumine*, pre- red from four pounds of alum and four pounds of sugar of lead r gallon of water, which is a solution of the acetate of alu- ine with a small excess of the sulphate. The Lancashire ca- co printers have, however, within a few years devised means which they have been enabled to combine in this style of inting the peculiar action of both mordants, and to secure, in considerable degree, the brilliancy of colouring produced by e one, and the permanency of the other; this important ob- ct is effected by impregnating the whole body of the cloth, evious to printing, with an alkaline solution of the oxide of n, and precipitating it upon it; the operation is known to inters by the term *preparing* cloth, and the calico thus treat- l is called *prepared* cloth;—for this purpose take 16 measures a solution of caustic potash at 20° T., and add to it one mea- re of the oxymuriate of tin at 120° T.; pad the cloth with is solution, without heat, and dry it the same day;—fix (pre- pitate) the oxide of tin by winching the cloth through a solu- on of sal ammoniac of 6 oz. to the gallon; then wash well, and ry for printing.

### *Steam Cochineal Pink.*

Take seven pints of a decoction of cochineal of 2 lbs. to the allon, one pint of double acetate of alumine; thicken with tarch; when boiled, and while yet hot, add 4 oz. of oxalic acid, nd cool as fast as possible;—steam twenty minutes;—print, of ourse, on prepared cloth. Oxalic acid is added to all steam co- ours, containing cochineal, to counteract the effect which the alts of alumine have upon that colour, that of giving the pink purple hue.

### *Steam Yellow.*

Take one gallon of a decoction of Persian berries at 8° T., vhen nearly cold, add 12 oz. of alum and one gum water, mixed vell together, and dissolve in it two ounces of nitre;—print on prepared cloth, and steam 25 minutes.

### *Steam Black.*

Take 2 lbs. of galls (nut galls) and 1 lb. of logwood chips,- boil the chips well, and then add the galls, and boil two or thr hours, so as to extract all the colouring matter, and then evap rate, or add, as the case may require, to make one gallon.- Thicken with equal parts of starch and flour; while thickenin add 4 oz. of the sulphate of iron; when cold, add half an oun of nitrate of iron, including one-eighth of an ounce of nitrate copper. Steam 20 minutes, after ageing one week.

### *Steam Lilac.*

Take one part of a decoction of logwood at 6° T., one pa of a decoction of peachwood at 8° T., one and a half part double acetate of alumine, and four gum waters.

### *Park Olive.*

Take three parts of a decoction of nut galls, of 2 lbs. to t gallon, one part of a solution of nitrate of copper, of 1 lb. the gallon, ten parts of a decoction of Persian berries at 4° T containing three-quarters of a pound of alum *per* gallon, a twenty gum waters at 34° T.; print, and steam 20 minutes.

### *Pale Drab, or Olive,*

Is prepared from one of the above, and ten more gum w ters.

### *Steam Orange.*

Take one measure of a decoction of cochineal, of 2 lbs. to t gallon, and ten measures of a decoction of cochineal at 4° T.

### *Another Steam Orange.*

Take four parts of Persian berry liquor at 10° T., three pa of a decoction of cochineal, one part of double acetate of a mine; thicken with starch, and, when nearly cold, add 4 oz. oxalic acid to the gallon. Print, and steam 20 minutes.

### *Steam Cinnamon.*

Take a quarter of a gill of double acetate of alumine, and three-quarters of a gill of a decoction of logwood, at 6° and two ounces of starch; boil, and, when nearly cold, add and a quarter ounce of oxalic acid, and mix the whole with ven quarts of the above orange. Steam 20 minutes, and th pass the goods through caustic potash ley, at 20° T., with ei ounces of alum per gallon.

*Another Cinnamon.*

Take one and a half gill of a decoction of Persian berries at ° T., one and a half gill of a decoction of cochineal, 2 lbs. to e gallon, four and a half gills of a decoction of logwood at 6° , four and a half gills of double acetate of alumine; thicken th starch, and, when cold, add two and a half ounces of oxa- acid. Steam 25 minutes.

*Park Cinnamon.*

Take one pint of a decoction of Persian berries at 12° T., ree gills of a decoction of cochineal of 2 lbs. per gallon, three lls of double acetate of alumine, eight ounces of flour; thicken, d, when cold, add three ounces of oxalic acid.

*Steam Bronse.*

Take one and a quarter pint of a decoction of Persian ber- es at 10° T., one and a half pint of a decoction of cochineal, 2 lbs. to the gallon, half a gill of double acetate of alumine; icken with starch, and, when cold, add one ounce of oxalic id. Steam 25 minutes.

*Another Steam Cinnamon.*

Take one gill of a decoction of Persian berries at 10° T., one ll of acetate of alumine; thicken with starch, and add, when old, two ounces of oxalic acid.

*Steam Chocolate.*

Take twelve gills of cochineal decoction of 2½ lbs. per gallon, our gills of a decoction of Persian berries at 10° T., four gills f a decoction of logwood, of 8 lbs. per gallon, two and a half unces of muriate of ammonia, and nine ounces of alum;— hicken with starch, and steam 25 minutes.

*Steam Deep Brown.*

To the foregoing steam chocolate, add one ounce of the sul- phate of iron, and steam, after ageing a day or two.

*Steam Brown,* (another.)

Take two quarts of a decoction of Persian berries at 10° T., two quarts of a decoction of peachwood at 10° T., one pint of decoction of logwood at 6° T., six ounces of sulphate of iron, and six ounces of cream of tartar.

*Prussian Steam Blue.*

Take one gallon of water, one and a quarter pound of prus- siate of potash, one and a quarter pound of tartaric acid. Dis-

solve the prussiate of potash first, and then the acid. Thicl the clear liquor with starch. Print and steam, and then wi the cloth in a solution of chloride of lime, of one ounce to gallon.

Five ounces of sulphuric acid, and one and a quarter pound tartaric acid, or, what is cheaper still, one and a quarter pou of bi-sulphate of potash, may be substituted for the one an quarter pound of tartaric acid directed.

When this colour (or rather mordant) is printed on *unp pared* cloth, and dyed in madder, it becomes a bright purp called by the English printers *French purple.*

### *Steam Green.*

Take one measure of a decoction of Persian berries at 4° and one measure of the Prussian Steam Blue above; mix, a thicken with starch. This and the preceding colour are bo easily discharged by caustic potash, or even by a solution common soap.

## DISCHARGES PRINTED ON PADDED GROUNDS.

### *Black and Whites.*

Take one gallon of aceto sulphate of alumine, prepared fr pyrolignate of lime and alum, at 22° T., three gallons of ir liquor at 12° T., and one gallon of water; mix.—Pad the cl in this liquor at a temperature not exceeding 220° Fahr., and i mediately afterwards print it with the following *acid paste:*

Take lime, or lemon juice, boiled till it have a specific gr vity of 30° T. Thicken with 5 lbs. of British gum to the g lon. If the paste be too thick, the printer may be furnish with unthickened acid at 30° T., and be allowed to reduce consistence to suit the engraved pattern. Some printers u the acid at 20° T., or 25° T. Something depends upon the n ture of the pattern: a more concentrated acid is required for fine engraving than for a coarse one. The super-sulphate potash has long been employed in the discharge pastes, for th style of printing, as a substitute, in part, for the citric aci which is more expensive: the following formula is recommen ed by a skilful calico printer, recently from England.

Take 1 $\frac{7}{8}$ of a gallon of citric acid (crude as above) at 20° T 26 oz. of super-sulphate of potash in crystals; thicken the citr

d with starch, (for medium, or average figures, 4 lbs. to the llon,) and when well boiled, and while yet hot, add the sul- ate of potash. After printing, age the pieces seven days;—fly ng them at 200° Fahr.; rinse, edge up, wash, and dung them econd time at 180° Fahr.; after which they are rinsed, edged, d washed again, and then dyed in a bath of ground logwood, bs. to the piece;—bring up to a boiling heat in one hour, and il fifteen minutes. The subsequent processes are the same as er madder dyeing, with the exception of the clearing in the ution of chloride of lime, which is omitted in this style of rk.

If madder be substituted for the logwood in this style, we ob- n the same effect, and a much *faster* colour, but rather infe- r in point of depth and beauty; the difference is not so great, wever, especially if a little logwood be used in conjunction th the madder, that this consideration alone should determine e printer in the use of the latter; the logwood dye is alone em- yed by the English calico printers, and it would be impossi- e for our printers to compete with them in our own market, d use so expensive a drug as madder, for it is difficult for buyers distinguish clearly the one from the other, and even if they uld do so, the lower price at which the logwood blacks can be orded would determine the choice in their favour.

The theory of this style of printing is extremely simple; the ordant padded upon the cloth is the pro-acetate of iron; the id of the paste decomposes this salt on the parts on which it applied, combines with the oxide forming a soluble salt, which dissolved out in the processes of dunging and washing pre- ous to dyeing; the acetic acid is expelled for the most part, in pour by the heat used in printing, and by the subsequent ex- sure to the air. The sooner the pieces are printed after pad- ng the better will be the discharge; if the printing be delay- , the acetate of iron becomes decomposed, and the protoxide tracting oxygen from the air passes into the peroxidized state, which, when combined with the cloth, it is insoluble in the tric, and even in the sulphuric acid, under any circumstances which it is safe to apply them to the cloth. Where a delay printing, however, is unavoidable, the work will not suffer uch for twenty-four or forty-eight hours, if the pieces be rolled ry hard and smoothly upon the wooden shell, from which they e printed by the printing machine.

It is obvious, from the foregoing remarks, that the success of is operation, so far at least as good whites are important, de- nds much upon the mordant being as free as possible from the roxide of iron. On this account it will be found better to repare the iron liquor for this purpose by using a large excess

of clean iron turnings, and stopping the solution as soon as liquor has acquired a specific gravity of 12° T., instead of c tinuing the process till it stands at 18°, and afterwards re luc it by water to 12° T., as I have already directed for the pre ration of this mordant for other purposes; in this case, pro bly less of the iron is peroxidized and the large excess of a tic acid holds that which is peroxidized in solution, and preve its deposition on the cloth. The pyroligneous acid should h a specific gravity of 7° T., before the iron is added. The C peachy logwood is decidedly superior to the St. Domingo Bay of Honduras logwood, for this, as, indeed, it is for ev other style of work, in which a good black is wanted.

Some calico printers use a small portion of glue in the l wood dyeing bath, but it is quite useless; it was originally troduced under the idea that logwood contained the tanning pr ciple, which is precipitated by gelatine; but this opinion is c troverted by Dr. Bancroft, and I can affirm from repeated tr on a large scale, that it is unsupported by facts.

Very recently the idea of substituting the dry extract of l wood for the wood has been revived, and the article is now ported to a considerable extent for the use of dyers. I l made a few trials of this article, and with good results as to lour, but have not found it more economical in use than wood. Dr. Bancroft says that where the decoction of logw has been speedily evaporated, the extract is soluble in w and in alcohol; but where the inspissation has been effe slowly by exposure to even a hot summer atmosphere, the louring matter will absorb oxygen, become insoluble in w and that the colours dyed from it will prove much more fugi than those produced by the decoction when recently made; a observes, that having once attempted to substitute the dry tracts of various dyeing drugs, for the drugs in their natu state, and such attempts having, in almost every instance, b attended with disappointment and loss, by reason of the chan to which colouring matters are liable by the operations necess for their extraction, cautions those who may be disposed to milar undertakings.

### *Crimson Figures on a Black Ground.*

If the cloth padded with the iron liquor be dyed up bef printing and afterwards printed with a thickened solution of muriate of tin, and simply washed, we have a beautiful crim instead of white figures on the black ground. In this operat the protoxide of tin is converted into a peroxide at the expe of the peroxide of iron, and is precipitated upon the calico combination with the colouring matter of the logwood, wh

e muriatic acid of the tin combines with the protoxide of iron, rming a soluble salt, which is washed away. From four to x ounces of crystals of muriate of tin *per* gallon will answer is purpose. Thicken with starch. The temperature of the inting stoving room must not exceed 140° or 150° Fahr.

### *White Figures on a Red Ground.*

Pad in old red liquor at 12° T., at a temperature not exceed- g 180° Fahr. The liquor should be thickened with one-thir- th part of *gum red.* Age two or three days, and then print the same discharge as for *black and white*, only the citric id at 20° T., will generally answer, unless the patterns on the ller be very fine. The goods should be dunged three times r this style: first, at 165°,—second, at 140°, and, third, at 130° ahr., and twice dyed in madder.

### *Black and White Figures on a Red Ground.*

Print on the padded red ground before dyeing by a two-co- ured printing machine, one roller in the acid paste of the last yle, and the other in iron liquor at 18° T., thickened with our:—Age seven days, and dung three times, and dye twice madder, using at each dyeing four pounds of the best Dutch op, or five pounds of the best French madder with two ounces f sumach. The first dunging in this style should be at a tem- erature of 170° or 175° Fahr., to prevent the black from start- ng. The black obtained in this way is not good, as the mad- er is shared between the aluminous and iron mordant, and pro- uces a dark chocolate rather than a black. The cheapness of he style is its principal recommendation. Where a good black s required on a madder red ground, the black should be first rinted and dyed up, and the cloth afterwards padded and dyed or the red; the reverse operation cannot well be done and ob- ain a bright red, because the loosened iron mordant will be lia- le to fix to some extent on the red ground in the dyeing bath. When the style of printing is such as to require the black to be pplied last, it is usually printed in chemical black by the block r surface roller.

### *White Figures on a Chocolate Ground.*

This style is conducted on the same general principles as those f the white discharges on black and red grounds. The pieces nust be printed immediately after padding, as in black and whites, nd for the same reason, then aged 7 days, and dunged and dyed s for the red ground, except that the dunging must be conducted t a higher temperature, and particularly the fly dunging, which hould be at 180° Fahr. The aluminous and iron mordant must

be proportioned to the shade required. The pieces padded printed, and dyed in this style, are frequently partially blo[ck]ed or padded afterwards in the aluminous mordant, and dyed u in quercitron bark; in which case a part, or all, of the figure are made yellow.

### *White Figures on a Bronse Ground.*

The method of producing a bronse ground has already bee described under the head of *bronse colour;*—for the discharge take two pounds of crystals of muriate of tin, and dissolv[e] i one gallon of water, and thicken with British gum;—print fo[r] discharge and wash. Nearly as good a result may be obtained by printing a discharge made by dissolving three pounds of pro tosulphate of iron, and four ounces of sulphuric acid in one gal lon of water, and thickening with flour or British gum.

The rationale of the action of these two salts on the brons from manganese, is the same: take, for illustration, the protomu riate of tin,—the protoxide of this salt abstracts a portion of th oxygen from the manganese, becomes itself converted into a pe oxide of tin, and reduces the peroxide of manganese to a pr toxide; in this state the excess of acid of the muriate of t combines with the protoxide of manganese, forming a sol salt, and the remaining acid remains in combination wit[h] t peroxide of tin, and both salts are dissolved out.

The bronse from manganese may also be discharged by t oxalic, and even by the tartaric acid, but the former is too e pensive, and the latter requires several weeks exposure to t air, to complete the discharge.

### *Buff Figures on a Bronse Ground.*

After printing the super-sulphate of iron upon the bronze fro manganese as above, winch the goods in lime and potash liquo as for raising buffs.

### *Chrome Yellow Figures on a Bronse Ground.*

Pad and raise the bronse as before directed, then take 1 gallo of water, 4 lbs. of nitrate of lead, 2 lbs. of tartaric acid, and 2 lb of crystals of permuriate of tin; dissolve the nitrate of lea and tartaric acid in the water, thicken with gum Senegal to th required consistence, and then add and stir in the crystals tin; print on this colour, and when the cloth is dry run it throug a weak solution of chloride of lime; then wash well, and wind the cloth in a solution of the bichromate of potash, allowing tw ounces to the piece.

In the foregoing process, the manganese is discharged by th protomuriate of tin on the principle already explained above; th

tric acid is neutralized by the lime of the bleaching powder, d the chlorine peroxidizes the manganese of the ground. The ndency of the nitrate of lead to crystallize unfits it for this rpose; the tartrate of lead being very insoluble in water, equally unsuited for this use; the tartrate is, however, soluble nitric acid, and in this state it exists in this discharge.

### *Yellow, Pink, Purple, and Blue Figures on a Bronse Ground.*

The yellow is produced as in the last. The red or pink, is e *spirit red*, or *peachwood*, *wash-off pink*, and the purple, e *spirit purple*, (vide chemical colours,) with the addition of om one and a half to two pounds of crystals of the protomu- te of tin to each gallon. The protomuriate in these cases, scharges the oxide of manganese, and the permuriate fixes the louring matter of the peachwood and logwood. The blue is oduced by dissolving Prussian blue, (more or less, according the shade required,) in a solution of the protomuriate of tin, two pounds to the gallon. All these colours should be thick- ed with starch, or, what is preferred, gum tragacanth. Some inters substitute the *cochineal pink* for the peachwood pink, which case a deeper colour is produced. The pink, purple, d blue, in the above, are necessarily very fugitive; but, the eat beauty of the style has nevertheless secured it a great le.

### *Yellow Figures on a Turkey Red Ground.*

Print on the dyed Turkey red ground a paste composed of o and a half pounds of nitrate of lead, and five and a half pounds tartaric acid dissolved in one gallon of water, and thickened, r the block, with five pounds of pipe-clay and one and a half unds of British gum, for the cylinder with British gum only; int and hang in a warm room for an hour or two. Make a solu- on of the chloride of lime of a specific gravity of 10° to 13° . at 60° Fahr. Warm this to 75° Fahr.; hook the pieces on frame, so as to expose a smooth and even surface, and dip em in this liquor, taking care to fetch up by raking a little ud, or sediment, from the bottom of the cistern, when the ods are entered, and to move the frame in this liquor all the me it is immersed, which may be about three minutes; then move the goods quickly to the rinsing cistern, and thence to e wash wheel. After the pieces are washed and squeezed, t while yet wet, winch them fifteen minutes in a solution of chromate of potash, allowing two ounces for a piece.

In this operation, there is first a double decomposition of the rtrate of lead and the chloride of lime; the tartaric acid of

the tartrate of lead seizes the lime, and liberates the chlor the oxide of lead is deposited upon the cloth in an insolu state, and the chlorine combines with and blanches the colou matter on the cloth;* secondly, the chromate of potash is de posed by the superior affinity of its acid for the protoxid lead, with which it unites, and forms a chromate of lead, wh is the same in composition as the beautiful pigment ca *chrome yellow.*

This style of discharge work cannot be practised on comm madder reds, owing to its severity on the colour generally; a without the greatest caution, even the Turkey red ground w suffer materially in the discharging process: to prevent th there should be allowed as little excess of chlorine as poss in the liquor. The excess of chlorine may be neutralized, eit by using an additional quantity of lime, or by adding to the quor a little potash, or soda; by which last means we in form a chlorate of soda, or potash, as far as it goes. My o experience in this process having been confined for the m part to trials and experiments in a small way, I cannot say w confidence whether the lime or alkali should be preferred. an excess of lime be used, the cistern should be well raked. agitated, during the immersions, as already directed. The mersion should never exceed five minutes, nor the temper 100 Fahr. Instead of dipping on frames, an arrangement s lar to that for fly-dunging and raising buffs, may be adva geously substituted, where much of this work is done.

*Black and Yellow Figures on a Turkey Red Ground.*

The yellow is the same as the last: the black is a chem black, printed on after the discharge and chroming proces are completed.

*Yellow Figures, on a Drab or Olive Ground.*

Take one gallon of aceto-sulphate of alumine, or red liqu and thicken with three and a half pounds of British gum, a three to four ounces of tallow. Dissolve the zinc in the red quor, and beat in the gum while cold; then warm the mixt to about 160°, add the melted tallow, and stir till the ing dients are well incorporated. Print with the block, and th pad the cloth with the drab, or olive, mordant, as the case m be, and, after suitable age, dye in quercitron bark. The thi ening will be found to resist the action of the padded morda and the printed parts will exhibit a bright yellow when dy

* The nitric acid, which held the tartrate of lead in solution, is also n tralized by the lime.

me colour-mixers add to the above resist, four ounces of sulate of zinc, and half a pint of berry liquor; but these additns are entirely unnecessary; the former is, indeed, perfectly surd, and has crept into use from a vague idea of the principle which it operates as a resist in the blue vat. (See "*resist ds*" and "*resist yellows.*"

*Chrome Discharges.*

The chromic acid has recently been discovered to possess the ne, or a similar property, for discharging most vegetable ours, that is possessed by chlorine.

If calico be dipped blue in a common indigo vat, and, after ying, padded in a solution of bichromate of potash of two unds to the gallon, neutralized with two pounds of soda, and ed a second time, white figures may be produced upon it, by nting on the following discharge:—

1 gallon of gum water, at 36° T.;
3 lbs. triple aqua fortis at 74° T.

Mix intimately, and print with the block. If the printing done with the cylinder, five pounds of tartaric acid, thickenwith gum Senegal, or British gum, will answer best; some sulphuric acid with the tartaric acid, but its liability to act the roller and doctors should forbid its use in any considera- quantity.

If nitrate of lead be combined with the discharge of nitric id, we have yellow figures on a blue ground. In like manner ost other vegetable colours may be discharged. I have not own of its being applied to the discharge of the Turkey red, d suspect it would not be sufficiently powerful.

The following beautiful style of printing with a chrome disarge, is of recent introduction.

Print a common reserve paste, and dip a light blue in the indigo vat. Then prepare the cloth with an alkaline solution of e oxide of tin, and fix it as directed in the preparation of cloth r steam colours. Print any steam colours that may be desired the rainbow form, and steam. Dip Saxon blue with the acete of indigo.* Pad with the bichromate of potash, as above rected. Lastly, print with the following discharge:—

1 gallon of gum water, at 36° T.;—

* The acetate of indigo is formed by adding to every pound of the concented sulphate of indigo three pounds of acetate of lead; the decomposition almost instantaneous. The indigo is transferred to the acetic acid, and the ide of lead to the sulphuric acid, which falls to the bottom. Decant the clear uor for use.

4 lbs. nitrate of lead;
3 lbs. triple aqua fortis, at 74° T.

No farther operation is required, but simple washing. I scarcely observe that the goods should be dried between each the foregoing operations, and aged, where the nature of the m dants require it.

Some printers add to the above discharge $\frac{1}{150}$ part of a so tion of muriate of iron, at 70° T., with the view, probably, of oxidizing the indigo, and thereby promoting the discharg process.

*Mixed Colours.*

Under this head may be noticed some of the numerous effe produced by one colour falling upon another, as they occur the successive operations of calico printing, whether they the result of chemical changes, or simply of mixture alone.

A black is affected by no other colour, unless it operate a discharge upon it.

A slight tinge of yellow gives to a deep red a scarlet hue.

Pale reds and yellow produce various shades of orange.

A blue falling on a yellow produces various shades of gre according to the depth and proportions of each.

A blue falling on a strong red produces a chocolate, or d plum colour; on pale reds various shades of plum, purple, what the printers call a bloom, according to the depth of e of the constituent colours.

A drab, purple, or buff (from iron) falling on a yellow, for various shades of olive.

A drab, purple, or buff (from iron) falling on a red, differ shades of chocolate.

A yellow, falling on a chocolate, a brown, or snuff colour.

The foregoing remarks are more strictly applicable to wh are usually termed fast colours; but, even in that class, there w be found many exceptions, which are noticed and explained various parts of this article.

## DIPPING.

Dipping, in *Calico Printing*, comprehends a variety of pr cesses for applying, or fixing, the indigo dye upon the cloth.

It appears that there are plants, the products in various pa

the world, during the fermentation of which a green subnce is either formed or evolved, which, when combined with ygen, forms a permanent blue dye. This substance, comed in different degrees with vegetable and mineral impuris, is the indigo of commerce. The immense supplies for e arts, in England and America, are now, for the most part, rived from India, and known by the name of *Bengal* indigo. e price of indigo, at the present time, (1830,) ranges from e to two dollars per pound. If the samples in the market be bjected to an accurate analysis, there will be found a corresnding variety in their intrinsic value. As this is one of the ost costly drugs in use, it is a matter of great importance to e dyer to be able to have some method of determining the relive value of different lots in the market: without this knowlge, let the skill of the dyer be what it may, a fortune may speedily lost in operations on a large scale. Dealers in indiare generally governed in their purchases by the colour. In is respect, all the varieties met with in the market are referred three classes,—the *blue violet* and *coppery* coloured indigo; these the blue is considered the finest and most valuable. e have the best example of this colour in the Guatimala or anish float indigo, now become scarce; but we observe it also the finer descriptions of Bengal indigo. The second quality the violet coloured, and the third and lowest quality is the pper coloured; the coppery hue is observable on rubbing two eces together.* Between these well marked classes there is und almost every variety and gradation, and considerable exrience is requisite to determine with much precision the relave value of different lots. The foregoing descriptions are inended to apply to the foreign indigo, known at present in r market, and particularly to the Bengal indigo. There is a ecies of indigo, occasionally met with in this market, and mafactured in South Carolina or Georgia, of a very inferior quay. It is in smaller cakes than the Bengal, of a dirty blue cour, and cannot be made to assume the coppery hue by rubng: this article is greatly inferior to the lowest qualities of the ast India indigo.

Another method of determining the comparative value of different samples of indigo is by throwing a few grains of each pon a red hot iron plate; the indigo will sublime in purple mes, and the residual ashes on the plate is a tolerable measure f the comparative impurities of each.

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* "When the first of these is sold for 9*s.* (sterling,) the second is commonly ought to be worth 7*s.*, and the third 5*s.* 6*d.*"—Vide Bancroft on Colours, l. i. p. 143.

If a given weight of indigo be finely pulverized, and digested first in forty or fifty times its weight of boiling water, then in alcohol, and, lastly, in muriatic acid, and afterwards be carefully washed and dried, the diminution in weight will indicate pretty accurately the amount of impurities. The indigo, thus treated, should sublime without residuum when thrown upon a hot iron plate.

Another means of determining the value of commercial specimens of indigo is the reverse of that described for testing the value of the chloride of lime, in treating of the manufacture of that article in this work.

There is but one solvent of indigo in its blue state, and that is the highly concentrated sulphuric acid. In order to accomplish this, the usual method is to take four pounds of the best oil of vitriol, and mix it with one pound of indigo in very fine powder; a considerable degree of heat is excited, with evident chemical action; the solution, if examined in a small glass tube during the process, will exhibit first a yellowish, and afterwards a deep blue colour; there is, during the solution, a slight production of carbonic acid, and of sulphurous acid fumes. The solution will go on without the addition of external heat, though it is quickened by that of the hot water bath. After the process is completed there remains a small deposite of sulphate of lime and other impurities, insoluble in sulphuric acid. The solution is nearly black, but when largely diluted with water assumes a deep blue colour. So intense is the colouring matter of this concentrated liquid, that the solution is perceptibly coloured when diluted with 500,000 times its volume of water. This is the celebrated Saxon blue of the dyers. The character of the acid employed in making the Saxon blue is a matter of great importance; it should have a specific gravity of 1·850 or 1·860 on Tweedale's scale. The makers of oil of vitriol, for this purpose, should reject in the distillation that acid which comes over first, and is contaminated with nitrous fumes, and reserve for this purpose only the most pure. It would be well worth the while to do this, and charge a higher price for it, as the presence of nitric acid is destructive to the indigo. On the Continent the glacial oil of vitriol only is employed. It is distilled by a great heat from the green sulphate of iron, and was formerly the only way in which this acid was obtained. It is more expensive, but the great value of the drug, upon which it acts in the preparation of the Saxon blue, renders it ultimately more economical. The manner in which the solution is conducted is also of importance; it is not advisable to add the whole of the indigo at once; it is best to take the full proportion of acid at once, and add the indigo by degrees, at intervals proportion

the violence of the action. It generally requires about twelve urs to complete the solution of one pound of indigo in four nds of acid. This process may, however, be expedited, and labour of grinding the indigo be saved by adding the indigo once in lumps of the size of chesnuts; the solution then goes more slowly, but as effectually as by the former method.

The Saxon blue solution was considered by Dr. Bancroft, and most writers since his time, as a sulphate of indigo, or a compound formed by the direct union of sulphuric acid and indigo. This view of its constitution seemed to accord with the fact that, if the acid of the solution be saturated by an alkali, a blue precipitate is thrown down, and the solution becomes clear; it is however, at variance with the fact that the precipitate thus formed will not, when dry, sublime by heat like pure indigo, and is, in fact, lost every property peculiar to the indigo before it was dissolved, except colour; it is also directly at variance with the facts observed by Berthollet; and more particularly examined and pointed out by Mr. Crum, in an admirable paper on the analysis of indigo, published in the Annals of Philosophy for January 1823, that the sulphates of potash and soda, and, indeed, most neutral salts, produce exactly the same effect, and that magnesia does not precipitate the solution at all, although it neutralizes the acid, and that the precipitate, when formed, is itself soluble in water. Mr. Crum has shown that, if pure sublimed indigo be employed, instead of the indigo of commerce, in the solution in sulphuric acid, there is no production of sulphurous or carbonic acids, nor absorption of air during the solution, and infers that there can be no oxidation of the carbon, or hydrogen, previously existing in the indigo; and since there is no gas evolved, and no carbon deposited, he concludes that the nitrogen of the precipitate exists in the same proportion to the carbon that it does in the indigo. From the foregoing, and similar facts, Mr. Crum very justly infers that the Saxon blue liquid is not a chemical compound of indigo and sulphuric acid; that the only operation of the acid in the dissolution of the indigo is to abstract a definite portion of combined water from the indigo, by which it is converted into a new and peculiar substance, soluble in sulphuric acid and water, which he has called *Cerulin*.*

The method of using the Saxon blue, in dyeing, is extremely simple: nothing more is necessary than simply to immerse the cloth or yarn in the liquid, sufficiently diluted, and after the requisite shade is obtained, to allow it to drain, and afterwards

* Mr. Crum's paper on the analysis of indigo may also be found in the notes to the 2d vol. of Dr. Ure's Translation of Berthollet's "Elements of the Art of Dyeing."

wash in water, and dry. Several writers have recomme the addition to the vat of potash, lime, or carbonate of l and others, to prepare the cloth, previously to immersion, alum and sulphate of lime;* but these practices are now g rally abandoned.

Unfortunately, this colour is by no means a fast one, a now seldom used for a blue, only except upon woollens. It in dyeing the beautiful, but fugitive colour, called *Saxo French green*, is described under that head in this work.

### *The Blue Vat.*

To fix indigo permanently upon calico, a more complex cess must be adopted. Before I proceed to describe the met of sitting the blue vat, I think it will contribute to a better derstanding of the subject to describe somewhat particularly constitution and habitudes of indigo in relation to the diffe agents employed along with it in the various processes of ca printing. Indigo appears to be a compound of a peculiar v table principle, which, in the natural state, is colourless and c gen, and affords one of those striking examples in which mistry abounds, of the entire change of properties produce the elements of a compound on entering into chemical co nation; here are two colourless substances, which, when mically united, produce one of the most intensely coloured c pounds with which we are acquainted. The proofs of this v of the constitution of indigo are numerous and conclusive. the juice be expressed from the fresh leaves of the indigo p and applied to bleached calico, a green stain is first produ but on exposure to the air it soon becomes changed to a blue: same thing happens if the expressed juice be allowed to rem of itself exposed to the air, or to an atmosphere of pure oxy gas. That the absorption of oxygen is the cause of this remar ble change in the colour of the vegetable matter is evident fr the fact, that if the agency of the air and oxygen from ot sources, be excluded, no such change takes place, and that oxygen thus absorbed has entered into combination with a ve table principle or principles, and actually constitutes an ing dient in the indigo, may be clearly proved by the fact, that oxygen thus united with the vegetable matter, may be abs ed from it, and made to enter into combination with anot body, and that the indigo thus robbed of its oxygen will converted into its natural green or colourless state†. The fa

* Vide Bancroft on the Philosophy of Permanent Colours, vol. i. p.

† The base of indigo as it exists in the plant, is no doubt perfectly c and with great care, the indigo of commerce may be so perfectly d d

y be most conveniently illustrated by operating on a few ins of the indigo of commerce; pulverize twenty or thirty ins of indigo; introduce it into a phial, and fill the phial two-rds full of water: on stopping the phial and agitating the mix-e, a slightly bluish tinge is imparted to the water, but no di-nution of the indigo is perceptible; add to the mixture a few ins of potash, and agitate again; no part of the indigo is dis-ved: indeed, to all practicable purposes, it may be said to be mpletely insoluble in water or in a solution of potash in its blue te; now add to this mixture some substance which has natu-ly a strong attraction for oxygen; such a substance is the pro-ide of iron as it exists in the protosulphate of iron; introduce n into the phial as many grains of this salt as you have done indigo, and agitate the mixture; in a few minutes the indigo ll have lost its blue colour, and have acquired that of a bright en, and become dissolved in the solution of potash; if the me experiment be made with the exception of leaving out the tash, the indigo will in like manner be changed to a green, t retain its insolubility in water. The true explanation of se appearances is this; the protoxide of the sulphate of iron s a stronger attraction for the oxygen of the indigo than the getable matter has, with which it is combined; the conse-ence is, a transfer of the oxygen from the indigo to the meta-protoxide, which is, by this accession of oxygen, changed from e state of the protoxide to the peroxide. The same effect is oduced upon the indigo; if, instead of the protosulphate, the drated protoxide of iron be used as it is precipitated from the lphate by the addition of an alkali to the solution. The pro-xide of tin either in its separate hydrated state, or combined th the sulphuric or muriatic acids, has the same effect in de-idizing indigo. The deoxidized indigo of the blue vat is or-narily green, but when perfectly pure indigo is operated upon the protoxide of tin, and the deoxidizing process has been ost complete, the indigo when precipitated from its alkaline lution by muriatic acid, is nearly white or colourless. The ual light green is probably owing partly to the presence of a all portion of the oxidized indigo combined with some foreign llow matters in the drug, and partly to the presence of a por-n of the hydrated protoxide of iron. That this change in in-go from the blue to a green, or a colourless state, is owing to abstraction of oxygen, is most satisfactorily proved by sny-esis as well as analysis; if a current of oxygen gas, or atmos-

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appear so; but it is so rarely that we obtain it in this state, that the green or perfectly oxidized indigo is frequently spoken of as the perfectly deoxidized natural state of the article.

pheric air, be passed through the green solution of indigo, absorption of oxygen takes place, and the indigo is instan precipitated in its blue insoluble state; this deoxidation and o dation of indigo may be alternately performed a thousand tim without subverting or altering its nature, showing a stabili of composition scarcely inferior to that of mineral substanc The deoxidation of indigo may also be effected by mixing alo with it vegetable matters, such as madder, sugar, wheat, bra &c. During the process of fermentation there is a great dema for oxygen for the production of carbonic acid, and if indigo present this oxygen is obtained from it. Fermentation is, ho ever, never resorted to in the dyeing of cottons in calico pri ing. It is applicable principally to the woollen dye.

It will be borne in mind, that in all cases, in order to effe the speedy deoxidation of indigo, an alkali should be added the indigo, together with the other ingredients, but that th agent is in no respect efficient in the deoxidizing process strict so called; it only facilitates the operation by dissolving as so as produced, the green indigo, and thereby preventing its ope ting as a mechanical obstruction to the deoxidizing agent a respects the remaining portions of blue indigo. Lime and m nesia have the same solvent power over deoxidized indigo as alkalis have; the former is extensively used in blue dipping. shall have frequent occasion in the course of this treatise to vert to the theory of the operation of various agents upon in go: sufficient has been said to prepare the reader for a better derstanding of the process of

### *Setting a Blue Vat.*

To a vat containing about 900 gallons of water, add

60 lbs. of indigo, ground very fine;
100 lbs. of green vitriol, (protosulphate of iron;)
120 lbs. of quicklime in fine powder.

It is of no importance, although some have thought so, whi of these ingredients is put first into the vat. The lime shou be slaked and sifted previous to putting it into the vat, or, wh answers an equally good purpose, and saves much trouble, ma after slaking, be mixed with water to the consistence of crea and after waiting a moment for the flint stones or other hard b dies to subside, be added to the vat.* Some printers prefer d

* The most perfect way of reducing lime to an impalpable powder, is throwing it cautiously into boiling water; the heat occasions a violent ebul and the violence of the action reduces the lime to a degree of fineness equal to that of a precipitate.

ving the copperas in a small quantity of hot water before add- it to the vat; to this there is no objection, provided it is not bjected to long ebullition, which has the effect to peroxidize e salt, and render it totally unfit for its office in the vat.

The proportion of lime above directed, is far more than is ne- ssary to decompose the whole of the iron, (as, indeed, it should ) Two hundred pounds of sulphate of iron require only 41 . of lime for this purpose. It is impossible, therefore, that y blue vat prepared in this way, should ever have iron in so- lion. The whole of the sulphate must be decomposed within e minutes after the agitation commences, and no change which er takes place afterwards, can ever make it soluble again; the prehensions, therefore, entertained by many dyers, of there ing too much copperas in a vat, is perfectly groundless. When e ingredients of the vat are all in, it is desirable to agitate them few moments in order to ensure a complete solution and mix- re; but as the indigo and oxide of iron are both undissolved first, and can only act when in absolute contact; they ought be permitted to subside and remain as near each other as pos- ble; in this state the protoxide of iron deprives a portion of e indigo of its oxygen, and the lime dissolves it; the vat is ain stirred up in order that the dissolved indigo may be dif- sed through the water, and thus, by alternate agitation and st, the process is carried on until all the indigo is dissolved, the solution is as strong as is wanted. The vat should be ell raked three or four times a day for two or three days, hen, after being allowed to settle for ten or twelve hours, it ill be fit for use. The commencement of the solution of the digo is indicated by the liquors assuming, when the vat is ked, a dark green, and its surface breaking into blue mar- ed veins; when the solution is complete, the liquor is of a eenish yellow, and the marbled appearance of the surface is ery beautiful, exhibiting in quick succession almost every co- ur of the solar spectrum, and terminating in a deep blue. These anges of colour bear a striking resemblance to those atten- ant on the oxidation of several metals when in fusion and to cel at a lower temperature, when exposed to the air, and are ndoubtedly attributable to the same cause.

The repeated agitation to which the blue vat is necessarily bjected, has a tendency to restore oxygen to the indigo, and econvert it into the insoluble state; the mere exposure of the rface of the vat to the air, even without any agitation, would time subvert the constitution of the vat; it is sustained in irect opposition to strong chemical affinities, which are con- tantly tending to change it; the indigo is continually acquir- ng oxygen, and the lime carbonic acid, from the atmosphere:

were no indigo taken out of it, the vat would gradually lose power, the indigo would be revived, (oxidized,) the protoxide of iron converted into the peroxide, and that portion of lime which had not become a sulphate by combining with the sulphuric acid of the copperas, would become a carbonate. Owing to this tendency of the indigo in the blue vat to attract oxygen and return to the blue insoluble state, the common manipulations of winching, or working the cloth in the liquor, as practised in other dyes, will not answer in this, for those parts most exposed to the action of the air would attract most oxygen and give the cloth an uneven colour: to avoid this, the cloth is stretched evenly by the selvages and attached by tenter hooks to wooden frames, so that every part of it may be equally exposed to the liquor when the cloth is immersed in the vat, and to the air when it is withdrawn from it. The cloth being thus arranged, is suddenly immersed in the vat, and in a short time becomes penetrated with the green solution of indigo; when lifted from the liquor it has the colour of the solution, a yellowish green, but by exposure to the air gradually attracts oxygen, and assumes the proper blue colour of indigo. A portion of the indigo penetrates the fabric, and, while there, attracts oxygen,—becomes insoluble in water, and permanently fixed in it. Whether this union of indigo with the cotton is to be regarded as a ternary chemical compound of the green matter of indigo, oxygen, and cotton, or as an intimate mechanical mixture, has not, to my knowledge, and, probably, could not easily be ascertained. Much of the indigo which is withdrawn from the vat with the cloth, runs back into the vat, and, for the most part, in a revived, or oxidized, state, and it is possible, that the same particle of indigo may be deoxidized and dissolved, revived, and precipitated a thousand times before it is ultimately combined with the cloth; if the oxide of iron and lime, therefore, were accurately proportioned to the deoxidizement and solution of the indigo in the first instance, they become feeble in their action before the vat is exhausted, and, after every day's work, a small proportion of copperas and lime should be added, to repair the waste, and care should be taken that the vat is deep enough to permit the exhaustion (i. e., to the point at which it is found profitable,) of the indigo before the sediment rises to the bottom of the frame.

The choice of copperas for the blue vat is a matter of great importance. It is well known to chemists that there are two distinct sulphates of iron, one of which is particularly adapted to the deoxidizement of indigo, and the other of no use whatever, and yet these two kinds are found more or less mixed in the copperas of commerce. The salt wanted by the blue dip

r is the persulphate, or green vitriol, whose pale green crys-
s cannot be mistaken for any other. The ochery matter,
th which it is usually found more or less mixed, and into
hich it has, when exposed to air or moisture, a constant ten-
ncy to change, is the persulphate, or highly oxidized sul-
ate; it has already assumed that state which we wish it to
quire, at the expense of the indigo, and is therefore worse
an useless, in as much as it has no action whatever on the in-
go, and serves merely to add to the sediment in the vat.

The proportions of copperas, indigo and lime, which I have
rected, differ from those recommended by Berthollet and Dr.
ncroft; they direct one part of indigo, two parts of copperas,
d two of lime; there is the greatest diversity of practice in
is respect among calico printers and practical blue dippers;
me recommend one part of indigo, one and a half of copperas,
d two of lime; others one part of indigo, two copperas, and
ree lime. A part of this difference is, no doubt, to be ascribed
imperfect knowledge and observation, but more to diversities
the quality of the indigo operated on; some species of indigo
ntain two, and even three times the quantity of real indigo
at others do, and require corresponding differences in the pro-
rtions of copperas and lime for deoxidizing and dissolving
m. The proportions which I have given above, are such as
ave used with the superior qualities of Bengal indigo; for the
ferior descriptions of indigo, smaller quantities of copperas
d lime will answer. The exact form and size of the vats is not
portant; I prefer them seven and a half feet in length, three
d a half in width, and six and a half deep; they may be con-
ructed of wood, stone, or iron; in England, they are usually
ade of stone fastened by iron clamps, and cemented with Ro-
an cement; in this country, they are almost invariably con-
ructed of wood; iron vats would be altogether too expensive
re, and are rarely used in Europe. Whatever material be
ed in their construction, the great value of the dye renders it
ry important that they should be absolutely tight. It has
en the usual practice in the United States, to build the blue
ts of three inch pine plank grooved together, and joined by
rong iron bolts, and to ensure their tightness by sinking them
within a few inches of the top, in the ground, and *puddling*
out them in the manner tanners do with their vats. This
actice is attended with great risk: it is certain that pine cis-
rns cannot be made sufficiently tight to hold the liquor, with-
t puddling, and I should hesitate much to trust to so clumsy
expedient as external pressure from a bank of clay to render
em so, especially under circumstances in which a leak of con-
derable extent might not be detected. A sheathing of lead

will make them secure, but it is expensive, and, unless t thick, is liable to be broken in the operation of raking dipping. The cheapest and best plan, I have found, is to them on the inside with the same materials, and in the manner, as the bottoms of ships are sheathed; but, in it is better to locate the dye-house so that the vats m into an under story, where every part of them may be fr ly inspected; it is hazardous to trust to discovering le vats, which are in daily use, by the sinking of the liq night; a leakage near the bottom, which would scarcely tected, might make all the difference to the printer be profitable and a losing business.

*Reserve Pastes.*

It seldom happens that a vat is employed to dye calico form blue. It is more commonly the object of the printer impress figures upon its surface with a paste, which sha the indigo dye from penetrating its surface, and wh therefore, leave a white object upon a blue ground, piece has passed through the blue vat. The action of sists, or reserve pastes is, generally, not well understood stances which resist mechanically, such as flour, or water, or a paste of pipe clay, would remain in the va trated but a very short time; the paste would gradually and permit the indigo in its green state to reach the wish to protect, and the figures would come out of wheel but miserable whites.

Nor would a thickened acid act much better. It would tralize the lime, it is true, and precipitate the indigo, at the surface of the paste; but there would be great what is called a starting of the paste; that is, there wou bably be more acid in the paste than the lime could neu and, owing to the great solubility of acids in water, would be that the acid would trickle down from the p leave a mark in its course of a lighter shade than the ground.

Wax and resin have often been employed as a resist o blue vat, and still are, in silk printing; but they will not well defined mark, and it is difficult to clear away the wa wards.

Oily substances answer, to a certain extent. But the b resists are those substances which form with the lime an ins ble compound, and which, by oxidizing, as well as precipit the indigo, before it gets through the thickening, pr arrival at the calico in such a state as to colour it. Such stances we have in the highly oxidized salts of copper, whi

ssess, in relation to indigo, qualities diametrically opposite to ose of the salts of iron; the protoxide of iron has, as has already been shown, a stronger attraction for the oxygen of indigo, an the green or colourless principle of indigo has, and, under favourable circumstances, seizing this oxygen, reduces the indigo to its green state, in which it is soluble in alkalis, and sses itself to the state of a peroxide; the peroxides of copper, the contrary, have a weaker attraction for oxygen than the een or colourless base of indigo has, and, yielding up a portion its oxygen to the green base of indigo, restores it to its blue soluble state, and returns itself to the condition of a protoxide. his fact is easily shown by adding to a green alkaline solution indigo a small quantity of a solution of any of the peroxidized ts, or the hydrated peroxide of copper; the colour is instantly anged to a deep blue. The salts of copper are not the only bstances capable of affecting indigo in this way; the nitric, phuric and acetic acids, precipitate indigo from its green solun, in a blue state, by yielding up a portion of oxygen, with ich they are united, and, on that account, have sometimes en used in the composition of reserve pastes: the muriatic d, on the other hand, which contains no oxygen, precipitates ligo from its alkaline solution in its green state; but the salts copper are found most convenient, and the sulphate of copper e cheapest. The following formulæ are the best in use.

I. To one gallon of water, (ale measure,) add four pounds of phate of copper, and, for the block, thicken with ten pounds pipe clay, finely pulverized and sifted, two pounds of gum negal.—Dissolve the sulphate of copper in the water, and afwards the gum; then add the solution, by little and little, to e pipe clay, and mix well together.

For the cylinder the above may be thickened with one pound elve ounces of flour, and five ounces of British gum, (calned starch;) add seven pints of the solution of sulphate of pper to the flour, and beat the mixture into a paste; boil ten nutes; mix the British gum with the remaining pint of liquor, d add it to the flour paste while hot, and beat them thoroughl together. Some printers would add half a pint of concented sulphuric acid to the foregoing, but it will scarcely imove the resisting properties.

II. To one gallon of pyrolignate of lime, (see Pyrolignate of me, preparation of,) of a specific gravity, 17° Tweedale's Hyometer, add four pounds of sulphate of copper.—Dissolve the phate of copper in the pyrolignate of lime at a boiling heat,

let the sulphate subside, and decant the clear liquor, whi when cold, (60° Fahr.,) will have a specific gravity of abo 33° on Tweedale's Hydrometer. This is an example of do ble decomposition; a portion of the sulphuric acid of the s phate of copper seizes the lime of the pyrolignate, or aceta and the acetic acid, thus set at liberty, combines in turn wi the oxide of copper abandoned by the sulphuric acid; the r sulting solution is an aceto-sulphate of copper: more sulphate added than the acetate of lime will decompose, and we hav therefore, a mixture of the acetate and sulphate of copper.

III. To one gallon of water, add four pounds of sulphate copper, two pounds of acetate of lead, (sugar of lead.)

The salts may be dissolved separately, by heat, in half a g lon of the water each, and afterwards added together; a doub decomposition ensues, and, when the sulphate of lead has su sided, the clear liquor may be decanted, as in the last case. Th composition of this solution is the same as the last, but, owin to the superior purity of the acetic acid obtained in this wa is preferred by some calico printers; but it is twice the cost, a probably little superior to the last. In both cases the metho of obtaining the acetate of copper by double decomposition preferable to a direct mixture of the sulphate and acetate rea formed, which, however, is often done. The thickening f Nos. 2 and 3, should be similar, for block and cylinder, to th for No. 1. The experienced colour mixer, however, is awa that both the quantity and proportions of the materials used i the thickening must be varied according to the season of th year, or temperature, the delicacy, or coarseness of the patter to be worked, &c. The two last described pastes may some times be improved for the block by the addition of six or eigh ounces of linseed oil well beat in.

Many of the old formulas contain alum, but its utility is ver questionable. The list of reserve pastes could be very easil swelled to a great amount; but the reader may rest assured tha the foregoing will bear the test of experience, and are selecte from others, perhaps, equally good, on account of their simpli city and cheapness. They are intended to resist a vat capabl of dyeing a deep navy blue ground; where lighter grounds only are wanted, the salts of copper may be proportionally dimi nished; but the thickening must remain the same. Two, o even one and a half pounds of the sulphate of copper, to th gallon, will afford a paste sufficiently resisting for a sky blue.

For the manipulations in dipping, and the general manage ment of the blue vat, I cannot do better than to transcribe the

llowing directions from the article "Dipping" in Rees' Cy-
ppædia, which is evidently written by a person familiar both
ith the theory and practice of the art at that time.

"The cloth may be dipped an hour or two after printing, if
quired, but the whites are seldom so good as when kept three
four days. The paste gets hard and firm, part of the acid
aporates, and the solution of copper becomes more intimate-
incorporated with the cloth.

"Dark blues, in general, require from five to ten dips, or im-
ersions, according to the shade of blue required, or the strength
the vats employed." [Sixty pounds of indigo to a vat con-
ining one thousand gallons of water is the usual strength em-
oyed in common blue dipping.]

"If the vats are strong, five, or, at most, six dips, will give
very dark blue, almost black, the intensity of which will be
ttle increased by farther dipping; the labour is greatly abridged
y employing strong vats, but the whites are liable to great in-
ry, as the solution of indigo, when concentrated, acts very
rongly on the paste. On this account the first vat should in-
riably be the weakest of the series, and never stronger than
sufficient to produce a full strong blue at seven, or even eight,
mmersions. The second and third vats may be stronger, and
on to the last, which may be the strongest of all. The num-
er of vats, in a well arranged dye house, must depend greatly
the nature and size of the establishment; eight of 'one thou-
nd gallons' capacity each,' in one line, side by side, form a
od series: double or treble that number may be required; but
ith fewer, a dyer, whose quantity of work is limited, yet va-
ous, will find much inconvenience, especially when, by long
orking, the dregs or grounds have so accumulated as to re-
uire a repose of twenty-four hours at least, after raking up, be-
re the vats are fit to work again. Dark blues may be dipped
nd finished in the same vat, but it is more convenient to pass
em in succession through a series.

"When the piece is well hooked, and the frame ready, the
at must be well skimmed before the piece is entered. The
rface of the blue vat is always covered with a film of revived
ndigo, more or less thick, according to the strength of the vat.
his film it is necessary to remove before the frame is immersed,
therwise the revived indigo, which is no longer in solution, at-
aches itself, and adheres to the cloth in patches, producing un-
venness in the dye, especially in the first vat. When skimmed
he surface of the vat is dark green, but the blue film reappears
a few minutes; it should not be removed, therefore, till the
rame is ready for immersion.

"In five or six minutes the cloth has fully imbibed the dye,

and little advantage is gained, in general, by keeping it lon in the vat." [This is not strictly true, the depth of the will be increased by allowing the cloth to remain in the or twelve minutes, but the direction is, on the whole, cor as a longer dip, particularly in the first or second vat, is li to soften the paste injuriously.] "The frame is then lifted and placed slantwise, in such a manner that all the liquor wh drains from the piece falls down into the vat again. When ken out the cloth" [ground] "appears of a pale yellow green, if the vat is weak, but if strong, more inclining to a ber," [and the figures blue, from the precipitated indigo on t paste.] "This colour gradually changes, as the indigo, by a sorbing oxygen from the atmosphere, becomes revived, and five minutes the cloth appears uniformly blue; it is then rea for another immersion. Six minutes *in* and six minutes *out* a good general rule for dipping dark blues, as the cloth will that time have acquired the full effect of the vat," [see the co rection above,] "and *the green will go off* in little more th five minutes, though the vat be very strong. The bottom e of the piece retains the green hue the longest, because it is lo est in draining from the liquor; care must be taken, therefo never to immerse a piece till the bottom edge has been examin and found perfectly ready for the dip. The consequence of tering a piece into the vat while the bottom edge is green, is, might be supposed, that this edge will be the palest, the ind not having been revived and precipitated upon it equally with rest of the piece." [The caution and direction inculcated h are important; in addition to the precaution given, the fram upon which the cloth is hooked, should be inverted after eve dip, and airing, so that in the following dip the selvage, which w before uppermost, shall then be the most depending, and so o without this resort, it is nearly or quite impossible to dye bo sides or selvages of the piece of the same shade of colour.

"In dipping dark blues, the first dip is the most importan and, if it fails, the work is inevitably ruined. First, if the v be too strong, the whites will never be clear and sharp; secondl if, for want of due preparation, the cloth does not uniformly r ceive the dye, the goods will scarcely ever be even when finis ed. Thirdly, if, either from the paste being too strong, or th vat too weak, or not in proper order, the impression *starts*, runs, at the first immersion, the ground is sure to be freckl and uneven, and the whites bad.

"Against the first source of error, the knowledge of the fa ought to be a sufficient guard; but if unavoidably it should hap pen that the leading vat is too strong, there is no other remed than shortening the time of the dip, and keeping the frame i

r or five minutes in lieu of six, till the vat becomes reduced strength.

"If the paste be too strong; that is, if it contain too much phate, acetate, or nitrate of copper, it is liable to start or run the first vat, especially when laid on in large bodies" [by the ck, which is now seldom used:] "this evil, if not too great, y be remedied, by gently moving the frame up and down, ring the first two or three minutes after it is entered. It may o arise from the vats being too weak, and, consequently, con- ning too little lime in solution, and may sometimes be reme- ed by the addition of more lime. If in spite, however, of the otion of the frame, the addition of more lime, or of greater rength to the vat, the paste still continues to run, it is a sign e solution of copper is too strong, and the quantity must be mediately diminished." [This starting of the paste is better ovided against by the use of a lime vat, into which the frame dipped, and suffered to remain from three to four minutes be- re entering the first blue vat. This vat should be richer in me than either of the blue vats, and, just before using, it should thoroughly raked up, so as to diffuse as much lime as possi- e through the vat mechanically, in addition to that which is ld in solution. It should be quite milky with lime. The ame may be moved up and down with more freedom in this an in the indigo vat. By this means, a portion of the salts of pper is decomposed, and the oxide of copper is precipitated in insoluble state upon the cloth. Another capital advantage om this practice is, that the ground is better prepared for the ception of an even dye by the neutralization by the lime of ny oily matter in the cloth, resulting from imperfect bleaching, r accidental impurity, and thereby removing a frequent cause f the freckled and uneven appearance of cloth, which has passed hrough the blue vat. The smallest particle of oil, or any greasy natter, is fatal to an even dye in the blue vat; but other impu- ities, that would resist, or materially modify, the madder and ther dyes, will rarely affect this. The rule is, if the cloth vill take water evenly, it will take the blue dye, and not other- vise. The method of proving (as the dyers sometimes call it) he cloth, is this; into the bottom of a box, placed opposite a vindow, of sufficient width to receive the cloth, fix a small vooden roller near the bottom, and two other rollers two or hree feet asunder, near the ceiling of the room, so that the perator may pull the cloth first through the trough, which is illed with water, and afterwards over the rollers, and let it fall pon the floor, between him and the window, in such a way hat every part of it may pass successively between the eye and he light; in this way any parts, which resist the penetration of

the water, will be instantly detected, and such pieces should laid aside, and subjected to an additional boiling in pot- fore they are used for this style of work. This trial is, o made before printing, and renders it necessary to dry the cl again, before that operation can be performed. Some print are so particular about their work, as to subject every piece signed for blue dipping to this test; others content then- with trying a few pieces out of every bleached lot of 400 to pieces, and, if they appear well, to receive the rest on trust.]

"When the green is gone off after the first dip, the frame then moved on, and dipped in the second vat, taking care skim it well before the piece is entered. In this way, aft each immersion, the frame is moved on to the next succeedi vat, till it has received the number of dips required. This d pends on the strength of the vat, and the shade of blue wante but as, during the process of dipping, the vats continually g weaker, the goods, after a certain time, will require an adc tional immersion, or even two or three, to get them up to t strength of the first pieces that were entered.

"When the goods have received their last dip, and have quired their full shade of colour, they are taken off the boo and well winched in clean water; they are then, by the succ sive operations of washing, repeated as occasion may requi freed from the paste, and rendered as clear as possible, bef going into the sours. Souring is necessary to free them fr the last remains of the paste, and give a brightness and finish the whites. A solution of sulphuric acid, weak enough to borne in the mouth without inconvenience, is sufficient to d solve what oxide of copper is left in the cloth after good clea ing. The goods are immersed in this ten or fifteen minute after which they are well washed and hot-watered, and whe dry are finished, or ready for any succeeding operation. Th excellence of this kind of work depends on the clearness an purity of the white, and on the fulness and evenness of the blu

"When the vats become exhausted by working, they mu be *refreshed*. If a vat contains a tolerable charge of indig copperas and lime, and has been worked only once, raking u alone will be sufficient to put it in a state of working agai When again exhausted, copperas and lime must be added to di solve the revived indigo. The quantity must depend upon th size of the vat, and the supposed quantity of indigo which contains. From twenty to forty pounds of copperas, and thre fourths of that quantity of quicklime may be added at once t a vat of one thousand gallons, or thereabouts; and some ide may be formed of the effect which this should produce, by re collecting that one pound of indigo requires for solution abou

pounds of sulphate of iron [the writer here follows the directions of Berthollet, who probably operated on a very pure kind of indigo. I have recommended a little less copperas in proportion to the indigo, viz. as 10 to 6.] It is proper always to have an excess of lime in the vat, but it is wholly unnecessary to make those frequent additions of lime without any thing else, which is the practice of many blue dyers. It serves no other purpose but to fill the vat speedily with dregs, which ought to be avoided as much as possible, as, when they are accumulated to a certain pitch, it is necessary either to take them out, or suffer the vat to repose from 36 to 48 hours before it is fit for work after raking.

"If equal quantities of copperas and lime have been used when the vat was formed at first, and three parts of lime added for every four of copperas afterwards, any other addition of lime is wholly useless. Some idea may be formed of the state and condition of a vat by observing its appearance when raked up. In general, if it looks dark green or black, it may be presumed it contains a quantity of revived, or undissolved indigo, and copperas and lime are, therefore, necessary: this blackish appearance may, nevertheless, be occasioned by a very great excess of copperas, or sulphate of iron, the oxide of which, when recently precipitated by lime, is dark green; as this, however, could arise only through great ignorance, or accident, it is not often likely to be the case, as the quantity of copperas required to produce this effect must be very great indeed.

"When a vat rakes up yellow, or very pale yellowish green, it is supposed by some to contain too much copperas, and must be corrected by the addition of more lime. It is hardly correct to say that a vat contains any excess of copperas, since this salt cannot exist in solution with lime. A vat may want lime, and, in this case, it will be very weak,—of a pale yellowish green,—produce a very feeble blue, and the paste will invariably *creep*, to use the dyer's phrase, or, in other words, will run, and lose the sharpness and smartness of the impression, the moment it is plunged into the vat. This may be the case at the time the vat contains a quantity of revived indigo also, and rakes up black, so that no certain conclusion can be drawn from the yellowish appearance aforesaid. If a vat be weak, the froth which forms at the top during raking, is pale sky blue; the surface does not speedily break into marble veins, nor is it soon covered with a blue film. A strong well-conditioned vat, on the contrary, when raked up, becomes covered directly with a permanent and copious froth, the colour of which varies from a deep blue, when the vat is of ordinary strength, to a bright copper colour, which is always characteristic of a very strong solution,

and the surface, when skimmed, is in an instant covered with a thick film of revived indigo. This film, and the deep blue proper coloured froth, is the best and purest of the indigo, and called the *flower of the indigo* by the old dyers. In skimming great care must be taken that this is carefully preserved, and turned again into the vats at the time they are refreshed."

### *Method of starting a blue Vat.*

When a vat becomes so weak as to render the working of unprofitable a considerable quantity of indigo still remains in and the best method of separating it from the dregs, with which it is united, becomes an important problem. Where there is a spare empty vat the ordinary method is to *spring the vat*, as the dyer's phrase is, that is, add such an additional quantity of copperas and lime to the vat as will certainly dissolve all the remaining indigo, allow the sediment to subside, and then bail or pump off, the clear solution into the empty vat, to which a fresh quantity of indigo, lime, and copperas, may be added, for a new vat. If it be desired to recover the indigo in a solid state this may be effected either by precipitating the indigo from the solution by muriatic acid, which, uniting with the lime, forms a soluble salt, and the indigo is precipitated in a fine pulp to the bottom of the vat, and which, after pumping off the clear watery and a little stirring and exposure to the air, will become perfectly revived; or, it may be recovered by exposing the solution largely to the action of the air: to accomplish this, it is bailed from the vat and poured into wicker baskets placed over the empty vat, and suffered to fall through in streams from a considerable height; this process should be repeated till the liquor on standing shall become clear, or at least free from indigo. When the indigo has subsided, the clear liquor may be pumped or drawn off, and the indigo dried by a gentle heat or in the sun, and, if the object be to ascertain the exact amount of indigo consumed in a given space, carefully weighed. If the indigo be precipitated by muriatic acid, it is very pure, and, probably, from 2 to 50 per cent. richer than the indigo originally put into the vat; if recovered by exposure to the air it will probably contain more lime than when first dissolved; for which due allowance must be made. It requires one ounce of muriatic acid of specific gravity 1.180, to saturate the lime in one gallon of lime water.

It is always preferable to *start*, or clear out the vat, after every charge of indigo is worked up. The accumulated dregs will otherwise impede the operation of raking; upon which the success of the business very much depends. The practice of many blue dippers to allow the dregs to remain till they are touched by the frames in dipping, is slovenly and wasteful.

### *Protecting, or Mild Pastes.*

It is frequently an object with the calico printers to protect
adder red, and other delicate colours, from the action of the
he vat; to accomplish this object, a paste is printed over them,
hich must possess the property of the reserve pastes already
scribed, of neutralizing and resisting the action of the blue
e, and, at the same time, have nothing in itself injurious to the
lours thus protected; the common reserve pastes, made from
e salts of copper, will not fulfil this last indication, as the ox-
e has the effect to sadden the colours it is designed to preserve.
he salts of zinc are particularly well suited for this purpose:—

Take 1 gallon of gum water at 28° T.;
2 lbs. of sulphate of zinc;
5 lbs. pipe clay;
8 oz. soft soap.

Dissolve the zinc in the gum water, and then add it by de-
ees to the pipe clay, beating it first into thick paste, and gra-
ally thinning it down till the mixture is perfect; then warm
th the pipe clay mixture and the soap, and mix them intimate-
and strain.

### *Another.*

Take ½ a gallon of gum water at 34° T.; 2 lbs of muriate of
nc, or 1 gallon of solution of muriate of zinc made by satu-
ting muriatic acid of specific gravity of 33° T., with metallic
nc; thicken with pipe clay to the required consistence; it is
ell enough to make the paste a little too thick, so as to allow
e printer to reduce it at his pleasure to suit the particular pat-
rn, by stirring in a solution of sulphate, or muriate of zinc, of
e same strength as directed for the paste in the first instance.
he quantity of zinc used by different colour mixers is very va-
ous, some directing no more than 1 lb., and others 4 lbs. per
llon: something depends on the strength of the blue vat, and
e length of the dip; if there be too little zinc, the *resist*, to
e the dyer's phrase, will be imperfect; if there be too much
nc, this paste is liable to start, and trickle down upon the cloth
d resist the blue dye or parts intended to be coloured. The
nount of thickening will require to be varied with the tempe-
ture and season of the year. The pastes should be of such a
nsistence as to penetrate the cloth quite through to the back
de; and, in order to judge of the perfection of the printing,
is usual to examine the pieces before dipping upon the back
de. Mild pastes are always applied by the block, or, in some
re instances, by the surface roller. The printed pieces should
e hanged in a warm room at least 12 hours before dipping, and,

where time and room will permit, for a longer time, to give c pactness and hardness to the paste. The soap in the first form whieh I prefer, is added, to improve the working proper of the paste; some colour mixers use double and even tre the quantity here directed.

The salts of zinc do not resist the action of the blue vat, the prineiple of oxidizing the indigo like the salts of copp but simply by the mechanical impediment, which the prec tated oxide presents to the penetration of the blue dye; wh the sulphate is employed, the sulphate of lime formed upon surface of the cloth by the union of the sulphuric acid of zinc with the lime of the vat, an additional obstruction wo seem to be presented to the penetration of the dye; theo therefore, would lead to a preference of the sulphate to the n riate of zinc, though some printers speak in high terms of latter, which is more recently introduced into the art.*

Where very fine figures, (or *shapes*, as they are technica called,) are required, it is a frequent practice to add from two three ounces of the acetate, or nitrate of copper, to the fo going pastes. Nitric acid is sometimes a constituent par *mild* pastes:

Take 1 quart of nitric acid at 36° T.;
2½ lbs. of sulphate of zinc;
3 quarts of water thickened with 2 lbs. of gum Senega
5 lbs. of pipe clay.

Dissolve the sulphate of zinc in the gum water; then add acid, and, lastly, thicken with the pipe clay, and strain; the fect of nitric acid on the liquor of the blue vat I have alrea explained in speaking of *reserve pastes*.†

For very light shades of blue, where of course, the dip short, the following formula may be adopted;—

Take 1 gallon of water;
4 lbs. of sulphate of magnesia;
2 lbs. of soft soap.

Thicken with gum and pipe clay as before; the theory of t operation of this paste in resisting the blue vat, is similar that in which the sulphate of zinc is the resisting ingredient.

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* The protecting, or mild paste, may be applied either before or after t mordant is dyed up, the colour of which it is intended to protect from the a tion of the blue dye. It is as often used in the latter as in the former way.

† Arsenic acid is sometimes used in the same manner and for the same p pose as the nitric acid is in this case.

Mild pastes may be printed over a dyed colour, or over a inted mordant not dyed; in the former case they are printed ith narrow blocks, in the latter with wide ones.

### *Resisting Mordants.*

All the colours dyed on the iron and aluminous mordant, and variety of others, are produced on a blue ground by combining e mordants, or bases of the colours, with the pastes, which sist the action of the blue vat; dipping the pieces, and, after ashing, treating them as though the mordant, or bases, had een separately applied to the cloth, and not dipped. The oxide f copper is itself a mordant, and, unfortunately, a bad one, hough some account was formerly made of it by dyeing a faint ellow upon it with quercitron bark, as it is deposited on the loth in the common reserve paste.

### *Strong Resisting Red.*

Take 2 gallons of aceto-sulphate of alumine, (old red,) at 16° ., sightened with peachwood; 10 lbs. sulphate of zinc; 40 lbs. f pipe clay, and 10 lbs. of soft soap, and 8 gallons of the *stan- ard gum red*, (old red.)—Dissolve the sulphate of zinc in the ightened red liquor, then add the solution by degrees to the ipe clay, and beat it into a paste; then add the soap and gum ed, and stir till the ingredients are intimately mixed. Strain, rint, and hang in a warm room at least 24 hours before dip- ing.

### *Another Resisting Red.*

Take 1 gallon of standard red mordant, sightened with peach- vood, and thickened with 2 lbs. of gum Senegal; 2½ lbs. of pipe lay, 4 oz. of hog's lard; 2 oz. of olive oil; and 2 lbs. of a so- ution of muriate of zinc, specific gravity of 80° T. Add by legrees the thickened red mordant to the pipe clay, and beat hem well together; then warm the mixture, and add the oil and ard; stir well; and, lastly, add the muriate of zinc; mix inti- nately and strain through a coarse cloth.

### *Another Resisting Red.*

Take 1 gallon of standard red mordant at 16° T.; 4 oz. of verdigris.—Thicken with gum Senegal and pipe clay, as before.

The first of the foregoing formulæ I have found to answer a good purpose on the most extensive scale. The second is very similar, and, in composition, thought to be improved, both in the working and resisting properties, by the addition of the oil and lard, and in the substitution of the muriate for the sulphate of zinc; the last is capable of resisting the blue vat very well,

perhaps better than either of the others; but the acetate of c per is objectionable, on account of its acting as a mordant in madder dye and saddening the red, and particularly on p reds.

For paler shades of colour the aluminous mordant may be luted to any degree required, the other ingredients of the pa to remain the same for every gallon of the liquid mordant. a deeper shade of blue be wanted than what is familiarly kno by the term *sky blue*, the dip must be prolonged, (the streng of the vat being the same,) and the resisting ingredients, t is, the salts of zinc, or copper, as the case may be, must be p portionably increased; but this is seldom required. These p st are rarely printed by the cylinder; but, where this is the ca the pipe clay must be left out, and the necessary consisten given to the colour by the addition of more gum. It is scarc ly necessary to remark that, where paste of a thinner consi ence is requisite, the foregoing are to be reduced by a soluti of the resisting salts of zinc, or copper, of the same strength used in the first instance; indeed, it is usual in this, as in most all other cases, to furnish the printer with a pot of the t thickened mordant to dilute his paste to suit the pattern in ha

The condition of the blue vat, in regard to strength and p portions of materials, is a very important consideration in t style of printing; more, in fact, depends upon it than upon exact composition of the paste; an ill conditioned vat is t source of most of the miscarriages with which calico print are so often perplexed in this branch of the art. A fresh v composed of 60 lbs. of indigo, 100 lbs. of copperas, and 120 lb of lime, is well adapted for this, and, indeed, for most kinds *resisting* work. I have sometimes thought that an addition 4 lbs. of potash improved this vat, and, on the whole, recon mend it. If the vat contain too much lime, the margin of t red figure, when dyed up, will appear corroded; or, in the worl men's phrase, *white edged:* if the vat be wanting in lime, too weak, which is the same thing, (inasmuch as undissolved i digo in the bottom of it is wholly inoperative,) a somewhat s milar appearance is produced, though in a very different wa in the first case the lime, or, perhaps, the solution of indig *in its compound capacity*, dissolves away a portion of t paste and mordant; in the latter, the vat being weak, and t dip necessarily prolonged, the paste is softened, and, spreadin beyond the figure, resists the action of the blue dye on the bl ground; in both cases a white space is observed between the fi ure and the ground; but, in the former, this is produced at t expense of the printed part, and, in the latter, of the ground; t opinion, therefore, entertained by many printers, that the *whit*

*ged* work is invariably attributable to an excess of lime in the
t is quite erroneous, and calculated to mislead. In addition
the general directions, already given in treating of common
ue dipping, for the management of the blue vat, and which
ply, in the main, to this style of work also, I would insist
ongly on the obvious propriety in all cases, and in dipping
e resisting pastes in particular, of making preliminary trials
ery morning, after the renewal of the vat, by the addition of
sh lime or copperas, as well as after the first *setting*, of its
ness for the work, by dipping slips of the printed goods, and,
the case of the resist colours, even by waiting to see them
ed up before venturing on dipping whole pieces; these pre-
utionary measures necessarily consume some time, perhaps an
ur each morning, but they prevent miscarriages and loss; the
pper, who neglects them, let his judgment and skill be what
ey may, will occasionally meet with severe disappointment.
is advisable never to work this vat so low as in common blue
pping, but when it becomes too weak for this work, either to
rk up the indigo for other styles, or *spring* the vat and *start*
e clear solution into another vat preparatory to receiving a
sh charge of indigo. The immersion of goods printed with
sisting mordants in the lime vat, as recommended in dipping
mmon blue and whites, previous to the *blue dip*, must not be
itted.

After dipping, the goods should be thoroughly winched in
t water, and then washed, preparatory to dunging and dye-
g. The mordant being precipitated upon the cloth in an in-
luble state by the lime, the effect of hot watering and wash-
g, previous to dunging, is not to be avoided, as in goods print-
for madder dyeing in the ordinary way; but *souring* the
eces out of the blue vat is inadmissible in mordanted pastes,
r an obvious reason, and more particularly in resisting pastes
ntaining the iron mordant, to which these general observa-
ons are also intended to apply.

### *Resisting Chocolate.*

Take two quarts of iron liquor at 12° T., two quarts of ace-
-sulphate of alumine (*old red liquor*) at 21° T., and twelve
nces of acetate of copper.—Thicken with two pounds of gum
enegal and four pounds of pipe clay. In dark colours, contain-
g more or less of the iron mordant, the acetate, or nitrate of
pper may be used without sensibly affecting the shade, and
ford a better resisting paste.

### *Resisting Yellow.*

This is the same paste as the first formula given for the re-

sisting red, only it is usual to sighten this with a decoction the quercitron bark, instead of peachwood. After dipping, dye in the quercitron bark.

### *Resisting Black.*

Take one gallon of iron liquor at 12° T., four ounces of acetate, or nitrate of copper.—Dissolve the salt of copper the iron liquor, and thicken with two pounds of gum Sen and four pounds of pipe clay. Dye in madder.

In like manner, various shades of purples, olive, drab, other dark colours may be produced, by combining with pastes the mordants for such shades, and, after dipping, dye them in their appropriate baths, as heretofore directed for same mordants in the madder or quercitron bark, or both combined, as the case may require.

### *Resisting Buff.*

Take one gallon of acetate of iron, prepared from two pou of sugar of lead and four pounds of sulphate of iron, four lons of water, seventeen pounds of gum Senegal, twenty pou of pipe clay, and five pounds of soft soap.—Dissolve the in the iron liquor, diluted with the water, then add the mix gradually to the pipe clay in fine powder; and, lastly, add soap, previously warmed, and stir till the ingredients be roughly incorporated. Print, and after two days' age, dip f light blue in a vat of the same strength as before directed resist reds. The moment the goods are withdrawn from blue vat they should be plunged into another vat of clean wa unhooked from the frame, rinsed by winching, washed in dash wheel, hot watered, and dashed a second time. The l of the vat is sufficient for *raising* the buff in the operation dipping. If the foregoing operations for cleansing the go be found insufficient, the pieces may be winched in a w *sours* for three or four minutes between the *hot watering* the last washing. If the sours be used, at an earlier period the process, before the iron has become peroxidized, the col will be liable to be discharged.

This colour, when printed over a madder chocolate, form very pretty style, and one in considerable request of late yea The above paste affords a good shade for this purpose, but iron liquor may be more or less diluted, (the thickening, other ingredients, remaining the same for every gallon of liquid,) at the pleasure of the printer.

### *Another Resisting Yellow.*

Take four pounds of sulphate of copper, and two and a qu

pounds of acetate of lead; mix, and dissolve in one gallon water, and thicken with gum and pipe clay, as in other resing pastes: print, and hang in a warm room one day; dip in lime vat for some minutes, to precipitate the oxide of lead on the cloth, and then in the blue vat, prepared as for resistreds, according to the shade wanted. If only a very light de of blue be wanted, it will be necessary to give the cloth ther dip in the lime vat to decompose perfectly the nitrate lead; but if a deep shade of blue be the object, the lime of vat will be sufficient. The cloth is then rinsed, and washed, l *raised*, as the dyer's phrase is, in a solution of bichromate potash, as for other chrome yellows.

As the oxide of copper, as well as the oxide of lead, is preitated on the calico, there is produced a chromate of copper o, and this gives the colour a dull orangy appearance; a slight *ur* in the muriatic acid, diluted with sixty waters, will, by solving out the oxide of copper, brighten the colour in a rerkable manner; and, what is of still more importance, gives a degree of stability of which it has not been thought susptible.

Another method of producing the chrome yellow on a blue ound is this:—take three quarts of gum water, three and one-lf pounds of pipe clay, and four pounds of sulphate of lead, oduced in the double decomposition of alum and sugar of d in preparing the acetate of alumine; beat the whole into a ste, and add by degrees one quart of water, holding two and alf pounds of blue vitriol in solution: mix, print, and proed in all other respects as in the last case. This is a cheaper ocess than the last, but differs from it nothing in principle.

### *Neutral Paste.*

This term is applied to a paste, which is intended both to sist the action of the blue vat, and to discharge any mordant hich may be printed over it previously to dipping. It conns the elements of the common reserve pastes, and of the id paste, such as I have already described, for discharging e padded grounds for the black, red, and chocolate-coloured ounds. The resisting materials must be proportioned to the pth of the shade of blue, and the strength of the acid to the ordant to be discharged. Most direct the lime or lemon juice a specific gravity of 12° T. for reds, 18° for chocolates, and ° for blacks. I have not observed such wide differences in ese mordants with respect to the acid discharges; much more pends upon the strength of the pattern to be worked: a strongdischarge is required for an engraved roller than for the ock; and a finely engraved cylinder requires a much sharper

acid than a coarse one. The following formula will be fo to answer in most cases.

Take one gallon of lime juice at 18° T., one pound of s phate of copper; thicken it with five pounds pipe clay, a two pounds of British gum for the block; or with five pou of British gum for the cylinder. Some prefer a mixt of the sulphate, nitrate, and acetate of copper, inst d the sulphate alone, for the resist; but I think the sulph amply sufficient for any shade of blue ever required in th style of work. The super-sulphate of potash has also been su stituted wholly or in part for the lime juice, and in some o formulæ I find a diluted sulphuric acid alone used for the d charge; but the majority of printers, I think, now prefer t lime or lemon juice alone. The theory of the operation this paste has already been explained, in speaking of reser pastes and acid discharges on padded grounds.

### *China Blue Dipping.*

The object in this style of calico printing is the reverse that of common blue dipping: in the latter the printer's aim is produce white figures on a blue ground; in the former, to pr duce blue figures on a white ground; both processes, so far as t deoxidizing, dissolving, and fixing the indigo are concerned, a conducted on the same general principles, and with nearly t same materials.

Take 28 lbs of indigo;
21 lbs of red orpiment;
24 lbs of sulphate of iron (green copperas,) and
8 gallons of iron liquor at 8° T.

Grind the indigo and orpiment as fine as possible, in fiv gallons of iron liquor, and then add the sulphate of iron di solved in the remaining three gallons. For a deep blue, d lute this mixture with two parts of iron liquor, and thicke with starch; for pale blues, reduce the standard liquor with iro liquor thickened with gum to the shade required. No *agein* of the pieces is necessary after printing; indeed it is better t dip immediately before the oxide of iron becomes peroxidized

Two vats, therefore, are all that are absolutely required: will, however, be generally advisable to have three vats fo these solutions, two for lime and one for copperas, placed be tween the lime vats; in this way double the amount of wor may be done with the addition of only about fifty *per cent.* i the outlay for vats; but where much work is required in thi style, a series of 11, 15, 21, or more will be necessary: th series should constitute an odd number, so as to begin and en

series with a lime vat; besides these, it is desirable to have a sing vat to plunge the goods into after the last dip, and be- e they are unhooked from the frames. The copperas solu- n should have a specific gravity of from 4½° to 10° T., d proportioned in some degree to the firmness and weight the goods to be dipped; at least, this is the utmost range thin which good work can be done: with a weaker solution n 4½° T., the shade of the colour will be very faint; with a onger than 10° T., it will be very liable to be uneven.

The lime vats will require about fifteen pounds of fine sifted icklime for every one hundred gallons of water, or the same ount of lime may be added in the form of *cream* of lime, as commended in setting the common blue vat.

The following directions for the management of the dipping transcribe from an excellent article on this branch of calico inting, in Rees' Cyclopædia.

"When the pieces are hooked and properly arranged on the me, they are entered first into the lime, and the dipping pro- eds as follows:

| | | |
|---|---|---|
| 1. | Entry in the lime vat | 5 minutes. |
| 2. | in the copperas vat | 30 |
| 3. | in the lime vat | 10 |
| 4. | in the copperas vat | 30 |
| 5. | in the lime vat | 20 |
| 6. | in the copperas vat | 45 |
| 7. | in the lime vat | 45 |

"During the first five minutes in the lime the frame must gently rocked, or moved up and down, then drawn up and ghtened. The vat, both now and at every subsequent dip, well raked up before the frame is entered. When entered the copperas vat, rock five or six times, to detach the loose me from the piece.

"At the second entry in the lime, rock the whole time.

"At the second, and every succeeding entry in the copper- vat, rock five or six times as before, to detach the lime.

"At the third and fourth entry into the lime, rock five or x minutes, and now and then.

"The reason for finishing out of the lime, is to keep the ames and hooks free from the rust and incrustation of the pperas, which it loosens and renders more easy to detach nd clean; with respect to raising the colour, it makes no dif- erence whatever.

"When the piece comes from the copperas vat the second me into the lime, it will appear a grass green colour, if there

be a proper quantity of lime in the vat. If too little, piece will appear yellowish, and more lime must be added.

"Take off the pieces quickly after the last dip, and wi them briskly in the water pit a minute or two at the mos [A proper water vat at the end of the series, as recommend above, into which the pieces may be plunged immediat after the last dip, is preferable to waiting to unhook th from the frame; but in this case the winching cannot be d pensed with afterwards; to keep this water vat as clean as m be, I would recommend that a stream of water be kept ru ning constantly in at the top, while another is running out at orifice near the bottom, and which will carry off the mud a sediment, and supersede the necessity of an otherwise freque change of the water.] Get them into the sours, and, after winc ing over twice, or thrice, let them lie an hour or two, af which winch again four or five times, and wash well in t wheel. Hot water them, and wash again before hot sou ing, which is done in a sour of specific gravity $2\frac{1}{2}°$ T., heat to 180° Fahr. Winch the goods four or five minutes in th after which, wash, hot water, &c., and finish for drying.

"If the goods are kept too long out of the cold sour after last dip, the oxide of iron with which they are coated oxygena very rapidly, and the cloth becomes buff or orange. It is w difficulty that the iron is disengaged, and not without long very strong hot souring.

"The cold sours soon become foul with the loose superflu indigo, which is detached, and unfits them for light goods. l before the acid is saturated. In this case it is economical to two or three shovels full of fine well-beaten clay previou mixed up with water; when this is well incorporated with t sours, and suffered to subside, it carries down with it a gre part of the floating indigo, and renders them fit for use again.

"After every day's work, the lime and copperas vats mu be refreshed. From twenty-five to thirty pounds of lime, a cording to the size of the vat, and the number of pieces th have been passed through it, must be added every night. N harm can arise from the excess of lime, excepting the unnece sary expense of more than is required, and the accumulation sediment, or mud in the vat, which will soon require removin

"Ten pounds of copperas are generally added for eve piece that is dipped. This is suspended at the surface in wicker basket, till all is dissolved. It is quite unnecessary rake up the vat, as the fresh additions of copperas will incorp rate uniformly without stirring, which, by muddying the va may do mischief. Care must be taken to use the hydromet frequently to correct any deficiency, or excess, which may ari

the specific gravity of the solution of sulphate of iron. In aking new, or fresh copperas vats, after having brought them the standard on the hydrometer, add, to every thousand gal-ns, four or five gallons of the lime vat (raked up) and one ound of potash. This is to neutralize the superabundant acid the copperas. The grass green copperas is the best for this rpose; it contains the least free acid: the pale whitish green the worst, and when such is used, it will be proper, occasion-y, to throw into the vat about one pound of potash; and four five gallons of muddy lime water.

"When daily worked, the lime vats should be emptied out, d wholly renewed, at least once a month. The copperas vats e never wholly emptied; but when the mud accumulates so as be troublesome, and endanger the safety of the work by rest-g on the lower edge of the piece, it must be taken by a scoop shovel, proper for the purpose.

"The ground of those goods, which show much white, will, general, be sufficiently clear when finished, according to the eceding directions; the white is, however, greatly improved a gentle soaping, and one or two days' exposure on the grass.

"In general, better work may be produced in the winter than summer; in hot weather, the colour is liable to be uneven, tched, and mealy: the cause of this has not been well ascer-ined, though, in all probability, it arises from the increased tion of the sulphate of iron and lime, at an increased tempera-re; it is not unlikely that weaker copperas vats, would be und to act better in summer than strong ones, as the effect of mperature would thereby, in some degree, be counteracted.

"From the nature of the process of China blue dipping, it ust be evident that it must precede any other application of olours to which the cloth is intended to be subjected. If, for stance, reds, or yellows, are to be introduced, these must fol-w the operations of dipping, as they would inevitably be ined by repeated immersions in copperas and lime, or wholly ischarged by cold and hot souring."

I have said that the operations of blue dipping and China blue ipping are conducted on the same general principles, so far as e indigo is concerned: the latter is, in fact, a topical blue dy-g, and the same changes are effected on the indigo, by the al-rnate immersions in the lime and copperas vats, as are pro-uced by their mixture in the common blue vat. To begin ith the first operation, the indigo is partially deoxidized by e copperas and orpiment, with which it is ground, and the on liquor also does its part in this way; a portion of the in-igo, therefore, enters the first lime vat in the green state, and, eing dissolved by the lime, readily penetrates the cloth, the

oxygen of the air in the cloth, and, mechanically mingled w the liquor in the vat, is sufficient to renew the indigo wi h exposure to the action of the air, as in common blue dipp This oxidation cannot take place in the blue vat, for th v reason that the deoxidating materials are in constant cont with the indigo. The effect of the first dip in the copperas v is to supply the indigo with a fresh portion of the deoxidizi material, the proto-sulphate of iron, which is, to a considera extent, decomposed, and its protoxide precipitated by the li remaining in the cloth upon the fabric, and in immediate co tact with the indigo: the second lime dip again dissolves, a enables the indigo to penetrate the cloth, and so on through t other dips.

Although it is usual, and, as far as I am informed, the inv riable practice of calico printers to grind the indigo with copp ras or orpiment, or both, yet the propriety of the practice somewhat problematical; the effect of grinding must, by su repeated agitation and exposure of the materials to the air, ha a direct tendency to peroxidize the iron and effect that chan upon the orpiment (the acidification of the sulphur) at the exper of the air, which it is the obvious intent of their use to do at t expense of the indigo; and, if any part of the indigo be deo dized by these materials, as there probably is, the frequent e posure to the air during the tedious process of grinding, m reduce it again to the blue state. I should much prefer grind the indigo first, and adding the orpiment and copperas aft wards; the former in a concentrated solution, and the latter fine powder.

Some of the best calico printers in England have, within few years, discarded the use of orpiment altogether in the Chi blue paste, and with probable advantage, in as much as the wor is fully equal to what it is when it is employed, and with saving nearly equal to the entire orpiment heretofore used. I such cases, I believe it is usual to substitute the muriate for t sulphate of iron in the paste, and very recently the muriate h been much used by some English printers, instead of the su phate in the vats, and, it is said, with very decided advanta over the latter.

An improved, or rather a new method, is also recently intr duced by the Lancashire printers, of exposing the cloth to th action of the lime and copperas liquors; instead of hooking th piece upon the common dipping frame, the cloth is made to pa over rollers affixed to the frame, which is immersed in the l quor; it differs in nothing in principle from the common a rangement for fly dunging, except that the cloth, on leaving th vat, instead of passing off into a cistern, is wound again upon

ler, attached to the frame, and the movement is given by nd. This frame is hoisted alternately from the lime to the pperas eisterns, and the reverse; and such a speed is given to e rollers, in either case, as shall give the necessary time of posure to the action of the respective vats. I know of some inters who have produced excellent work in this way, but the rangement is more liable to miscarriage than the common hmes, and many have failed entirely in their attempts in it, d have gone back to the old method.

The proportions of the muriate, sulphate, or acetate of iron, d of orpiment, if used, employed for the printing paste by fferent printers, are very various; but it is a matter of very ttle consequence, within a considerable range, of which the rmula given above may be considered as about the medium. more of the deoxidizing materials be employed, more of the digo may be fixed upon the cloth permanently before dipping; less, more will remain to be done in the vats.

### *Pencil Blue.*

Pencil blue, so called from the circumstance that it was forerly applied by the pencil, is another form, in which indigo is pically fixed upon calico. It differs from the China blue in at, in this case, the indigo is completely deoxidized before its pplication to the calico, and requires no farther operation than mply printing and washing. To prepare this colour,

Take 1 gallon of water;
1 lb. of indigo, in very fine powder;
1 lb. of red orpiment;
1 lb. of potash made caustic with lime.

Dissolve the potash in the water at a boiling heat, and add to he solution half a pound of quicklime in powder; boil and stir ccasionally, for several hours; then let the sediment subside; raw off the clear liquor; make it up to one gallon, by the addiion of water; then add the orpiment, and dissolve at a boiling eat: when dissolved, let the sediment (for there will always be more or less insoluble matter in the orpiment) fall to the bottom; lecant the clear liquor; add the indigo, and stir till dissolved. Thicken the clear solution with gum Senegal, or British gum; f with the former, while it is yet hot; if with the latter, after it has become cold. This colour is printed either with the pencil, the cylinder, or with the block from the spring sieve.

Owing to the strong tendency of this indigo to attract oxygen from the atmosphere, this colour must be kept carefully excluded, as far as possible, from contact with the air. Some

printers thicken pencil blue with glue, when worked by t block.

The changes which take place in this process, are very sim lar to those which occur in the blue vat; and, as it regards th indigo, there is no difference; the sulphur and arsenic of the o piment both attract oxygen from the indigo: the former becom converted into sulphuric acid, and the latter into an oxide, an both uniting, form a sulphate of arsenic, while the indigo, re duced to its green state, becomes soluble in the alkali. S strong is the attraction of this mixture for oxygen, that its sur face rapidly combines with it when exposed to the air; and, a the indigo is, in that state, insoluble, it is extremely difficult t print a figure by the block, which shall have a uniform shade or an even *boundage*. On this account, it is always bounded in chintz patterns, where alone it is applied by the block, b some dark colour, and, in general, by black previously printed which gives to the blue figure the appearance of a defined mar gin, and disguises the unevenness of the colour. The orpiment or rather the new compound which it forms, is washed awa in the dash wheel. This colour by no means equals the Chin blue in depth, or beauty. The concentrated solution of potas necessarily employed in its preparation, is supposed to imp the colour of the indigo. The proportion of orpiment directe is rather larger than is required to deoxidize the indigo in th first instance, and larger considerably than many printers employ but, as the solution has a constant tendency to attract oxygen from the least exposure to the air, and, as some parts of the in digo require the deoxidizing process to be repeated again an again, an excess of orpiment is advisable.

The foregoing is as concentrated a solution as will often be wanted, but it may be made more, or less so, according to the shade required. The solution, when agitated, should exhibit a rich greenish yellow colour, and its surface become quickly covered with blue and purple veins; in short, it is a blue vat in miniature, both in principle and appearance.

### *Warwick's Green.*

A permanent topical green was, for a long time, a desidera-tum with calico printers.* The common aluminous mordant, and the pencil blue above described, it is obvious, would be incompatible compounds, as the moment they were mixed, the acids of the mordant would combine with the potash of the pen-

* The object was to combine the aluminous base, in a soluble state, with de-oxidized indigo, and to apply them cotemporaneously to the cloth, and afterwards dye in the quercitron bark.

blue, and both the indigo and the alumine would be precipited from their solutions in an insoluble state. The discovery the alkaline solution of alumine solved this difficult problem the art. To prepare this colour, dissolve in one gallon of the kaline solution of alumine, (which see) at a boiling heat (of ter) one pound of ground indigo, in the form of a paste, conning one quart of water, and three-fourths of a pound of red, orange orpiment. When cold, thicken the liquor with *high* ied British gum, three or four pounds to the gallon, if for the linder; but with less, if for the spring sieve. Fix the mornt as directed for the alkaline solution, and dye in quercitron rk, as for yellows. The public is indebted for the method of eparing the alkaline solution of alumine to James Thomson, sq., a celebrated calico printer, in Lancashire, and to Dr. T. O. arwick, an ingenious manufacturing chemist of Manchester, r the method of fixing it. To both of these gentlemen the de are under great obligations for numerous improvements in e art.*

*London Green.*

To one gallon of caustic potash ley, at 40° T., add two unds of crystallized muriate of tin, and fourteen ounces of indigo in fine powder; mix, raise slowly to a boil, and stir occasionally during the solution. As soon as the liquor boils, remove from the fire, and when cold, add as much muriatic acid as ill be necessary to saturate the alkali and redissolve the oxide tin. Then dissolve in the mixture twelve ounces of alum, and icken with gum Senegal.

The solution of tin and indigo may be kept for any length of me in a closed vessel; but when the acid is added, it must be ed the same day. Print with the block; this colour will not ork on the cylinder. If a *brassed* block be used, care ust be taken that it be cleaned, before using, from verdigris, herwise the colour will be injured. This colour is designed r working on a common teering sieve.

When printed, and dry, dip the cloth for two or three mites in a lime vat; wash well; expose to the air till the green s gone off, and then dye in quercitron bark as in Warwick's een.

In this process the indigo is deoxidized by the protoxide of n, and both are dissolved in the alkaline solution. The muatic acid saturates the alkali, forming a muriate of potash, re-

* Dr. Ure, in a note to the first volume of his Translation of Berthollet's Elements of Dyeing, &c." has, unintentionally, done injustice to Dr. Warck, by ascribing the whole merit of this valuable colour to Mr. Thomson.

dissolves the tin, forming a permuriate of tin, and, affording oxygen, precipitates the indigo in its green state; the alum added as the mordant for the yellow of the bark, and, together with the muriates of tin and potash, is mixed up into a paste with gum. In the fixing process, the lime decomposes the muriate and sulphate, precipitates the alumine, and so far dissolves the indigo as to enable it to combine with the cloth.

Some of the Lancashire printers have produced very good work with this colour, but it requires very careful management, and, on the whole, is scarcely to be preferred, even for the block, to Warwick's green. The indigo of the paste being in the solid state, it will not work with the engraved cylinder.

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Having described and explained the principal processes in calico printing, in their simplest forms, it remains to say something of the combination and order of these processes in what are denominated styles of printing, where several colours are produced on the same piece. I have partly anticipated this subject in several parts of this treatise, and particularly in speaking of the discharges printed on padded grounds, to which I have nothing more to add here. In the printing of *steam* and *ageing* colours, also, nothing more need be said; for, with the exception of the mixing the colours, the process is the same in these styles, whether one or ten colours are produced on the same pattern: the colours are all printed in succession, and raised by one and the same operation. It matters not which are applied first,* nor is there any such thing as chemical incompatibility among them; all the colours known in these styles may be produced on the same piece.

The circumstances are very different in printing fast colours, where the calico is usually wet after the application of each colour, or each class of colours, and where each colour or class of colours has its peculiar dye or raising liquor; here the observance of a certain order in the processes is indispensable, as otherwise the effect may be to destroy, by each operation, the colours which were raised or dyed by a previous one.

The general rule is to print and dye those colours first which will be least affected by the subsequent dyeing, or raising processes, and to print as many colours before each dyeing or

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* At least the only circumstance that must determine the order of the application of the different colours, is the mechanical convenience of the printer; it is usual to print those colours last which cover the most surface, as otherwise the drying of large figures in paste is liable to crumple the cloth, and render the application of after colours more difficult.

aising as can be dyed or raised in the same liquor. To make his subject more intelligible to the learner, and to give him a eneral view of the order and connexion of the processes in rinting fast colours, I will subjoin the following description of everal styles of work, which, together with those already described in different parts of this treatise, comprise the most important combinations in the art.

### *A Full Chintz, on a White Ground.*

The colours in this style are three shades of red, a black, two r more shades of purple, yellow, drab, olive, blue, green, and uff. Now, as the reds, blacks, and purples may all be dyed h the madder bath, and when produced are not much affected y the processes for raising or dyeing the other colours, the ordants for these colours are first printed and dyed, the direcons for which have already been given under the head of madder dyeing. These cloths being smoothly callendered or manled before the application of these first colours, they are printd with the widest and largest blocks. After dyeing and dryng, the cloth is again callendered, printed with the mordants for e yellow and drab colours, and dyed in quercitron bark. The gures dyed in bark are usually designed to fit and correspond ccurately with those previously dyed in madder; but, as the oth becomes stretched in the operations of dyeing and drying, e printing of these mordants, and, indeed, of all subsequent nes, is more difficult, and is necessarily done with narrower locks. These after printings are called in the art *grounding*, *alf-blocking*, or *printing off the grass;* the last term is deived from the circumstance, that formerly, after madder dyeng, (as well, indeed, as after other processes,) the goods were exosed to the action of sun and air in clearing the white grounds, practice which is now nearly exploded by the introduction of e compounds of chlorine for this purpose. The exact width nd length of the blocks, both for this and previous printings, re within certain limits determined wholly by the character f the pattern; if the joinings and adaptations be difficult, the lock must be proportionally small, and *vice versa.*

The olive colour is generally produced by the drab falling on e mordant for the yellow. The shade of olive will be deeper, from one to four ounces of Sicily sumach be added to the yeing in bark; but to produce a dark olive in this way, it is bsolutely necessary that the yellow be printed and dyed first, nd the drab afterwards; otherwise, such is the superior strength f the aluminous mordant for the colouring matter of the bark, iat a great proportion of the iron mordant will be dissolved way before any part of the colouring matter of the bark is at-

tracted by it, and fixed upon the cloth. Some printers try to obviate this difficulty by printing, ageing, and dunging the drab before printing the yellow mordant, but this is attended with nearly the same expense as two separate dyeings in bark, and never fully answers the purpose.

If the foregoing order of the processes had been reversed, and the mordants for the colours dyed in quercitron bark, printed and dyed before those of the madder, the result would have been very different: the madder colours last dyed would have been the same, but the yellow of the bark would have been changed from a red to a deep orange, the drab to a dirty purple, and the olive to a chocolate. This is owing to the superior attraction of madder for the mordants, which is such as to displace, under these circumstances, the colouring matter of the bark already combined with the mordant, and to enter into combination with it, to its (the colouring matter of the bark) almost entire exclusion. Hence, when colours are to be dyed both from madder and quercitron bark, the dyeing in the former must always precede the latter.

The buff may be next printed, and raised in the manner directed under this head. It is obvious that this colour could not precede or accompany the dyeings in madder or bark, as it would in either case have constituted a mordant, and dyed up a black or purple with the former, and a dark olive or drab with the latter. If any part of the buff colour fall, in printing upon the madder reds, it will change them to a chocolate; if it fall upon the yellow, it will change it to an olive: but these shades will be much darker if the madder and the bark colours have been dyed with a little sumach, from two to four ounces to the piece, according to the strength of the pattern.

The pencil blue is usually printed either along with the madder colours, or the last of all; in the former case the colour is applied with a whole block, and at about half the expense, but the blue is never so bright after passing through the madder and bark dyes.

The green is produced by the blue falling on the yellow, or *vice versa*.

Since the introduction of machine printing, the strong red and black of the foregoing style are more commonly printed by the engraved roller instead of blocks; but this variation causes no difference in the general conduct and principles of the operations described.

### *A Black, Resisting Red, and Green, on a Blue Ground.*

Print the black first, (generally with the machine,) and if any considerable part of the red cover the black figure, dye up the

lack after suitable age and dunging, and the grounds are cleared; rint a strong resisting red with half blocks, and dip in the blue at; cleanse, dry, and print the aluminous mordant on a portion f the blue ground, and dye in bark. If the red figure do not ver much of the black, the resisting red may be printed with hole blocks before the black is dyed up, and both dyed up together after dipping. The reason for these directions, with respect to the dyeing of the black and red, are, that it is impossible to obtain even a tolerable black where a red is printed over before dyeing, as the aluminous mordant will always divide ith the iron the colouring matter of the dye, and a chocolate, nd not a black, is the result.

### *A Black, Resisting Red, Green, Yellow, and White, on a Blue Ground.*

This style is the same as the last to the printing of the resist ed; the white is produced by printing a *mild paste* before dipping, which resists as well as the resisting red the action of the lue vat on the part so printed; after dipping, and dyeing in adder, the calico is printed again for a yellow, and dyed in uercitron bark; that portion of the yellow mordant which falls n the blue produces a green; that which falls on the white, a ellow. The last blocking is not unfrequently omitted when e have merely a black, red, blue, and white.

If a pale instead of a strong resist red be printed in the above tyle, a bright orange may be produced by the yellow mordant's alling upon a part of it, and thereby give an additional colour.

### *A Black, Plum, Resist Yellow, and Orange, on a Blue Ground.*

Print for a black, (usually with the machine,) and in pale red ith the block; dye in madder, and then print a resisting yelow paste, so that a part of it shall fall upon the white ground nd a part upon the pale red; dip pale blue, and dye in queritron bark. The pale or sky blue falling upon the pale red, roduces a plum, or what the printers call a bloom colour. hat part of the resisting yellow, which falls upon and protects portion of the pale red, produces an orange of a deeper or ghter shade, according to the shade of red in the first instance. he shade of plum, or bloom, will also vary with the particuar strength or depth of the pale red and blue, by which it is ormed. A characteristic of this style is, that it can have no reen in it, although it contains a yellow.

### *A Black, Red, Yellow, Green, and White, on a Blue Ground.*

The colours in this style are the same as in the last mentioned but one, but it is a far more difficult and more beautiful style. Print (with the two coloured machine if convenient) a mordant for a black and a *neutral paste;* then print, by the block, a strong resisting red, so that a part of it shall fall upon the white ground, and a part upon the neutral paste; dip for a sky blue, dye up in madder, and then block for a yellow, so that a part of the mordant may fall upon the white figures, produced by the neutral paste, and a part on the blue ground, and dye in quercitron bark. The great beauty of the style is the sharpness and delicacy of the figure caused by the neutral paste which cuts indiscriminately through both the indigo blue and the resisting red. If the resisting red be required to cover any part of the black, this colour must be dyed up first, and the resisting red and neutral paste printed with half blocks; at least nothing deeper than a dark chocolate can be obtained, if the red and black mordant be dyed up at the same time. If a chocolate be printed by the block instead of a resisting red, the blue may be wholly omitted, and a very pretty style obtained.

### *A Chocolate and Buff, on a Blue Ground.*

Print for a madder chocolate, and dye up; then half block it to resist buff, and dip for the shade of blue. The lime of the vat will be found sufficient for raising the buff, and nothing more is required than simply washing and cleansing after the dip: but for the particular management of this part of the process, see "Resist Buff."

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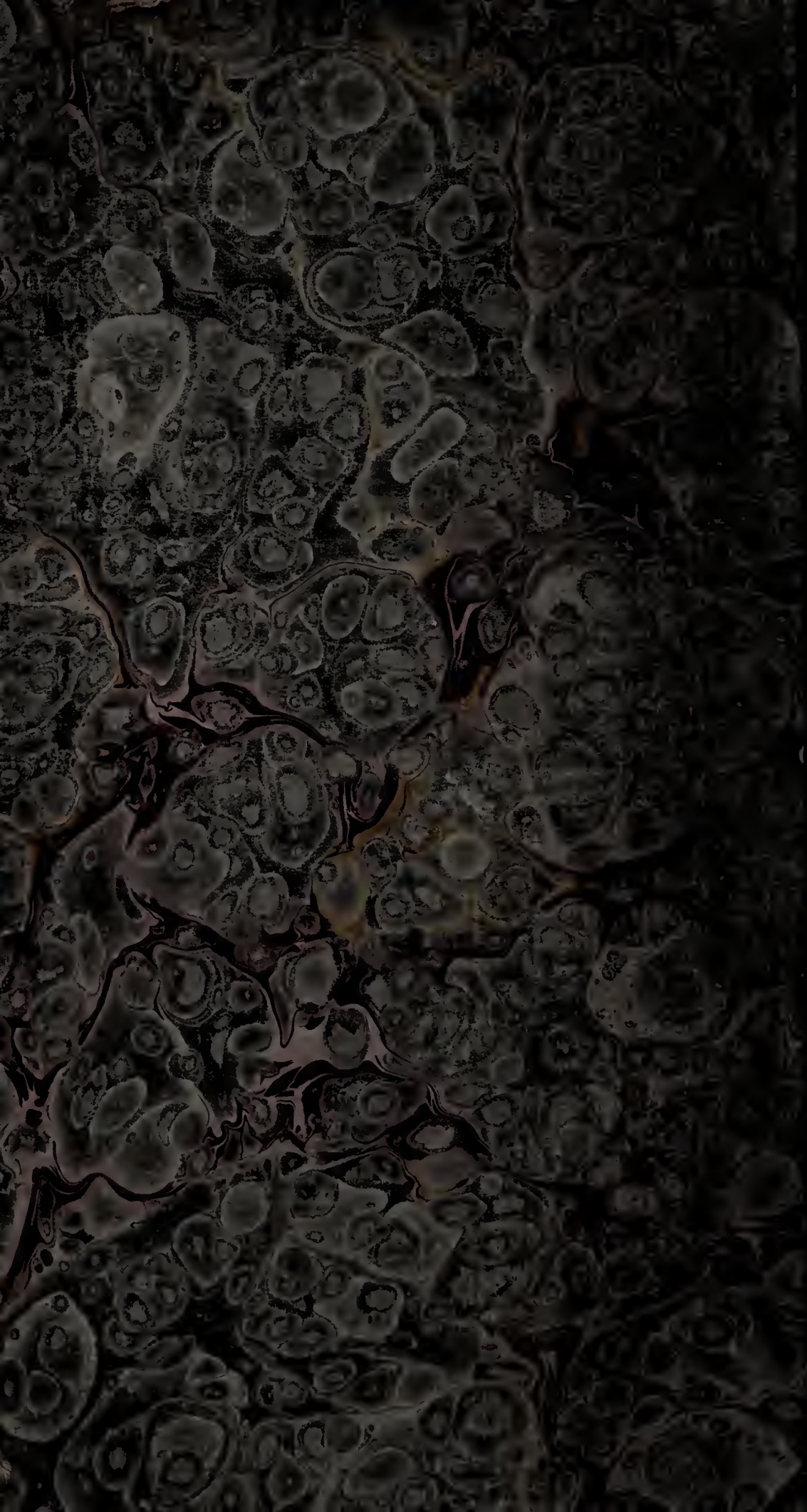
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